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INSTRUCTION MANUAL
FOR
DANA* SERIES 5000A
DIGITAL VOLTMETERS

DANA LABORATORIES, INC.
630 East Young Street
Santa Ana, California

Telephone: (714) 546-1130
TWX: (714) 546-2238

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Dana Digital Voltmeter 5100 A

DESCRIPTION

The Model 5100 A is identical to the 5100 except for the type of null detector. The Model 5100 A uses the Solid State null detector Part Number 400250. A Schematic Diagram of this null detector is enclosed in the Illustration Section, page 8.16.

Several times a year it may be required to reset the null detector to zero by using the screw-driver adjustment on the front of the null detector, (green-yellow, slots 20 and 21). This may be done by merely shorting input leads and adjusting to read all zeros. Before zeroing allow for 1/2 hours warm-up.

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1. INTRODUCTION

1.1 DANA SERIES 5000 DVM'S

Dana Series 5000 Digital Voltmeters are compact, rugged, highly versatile instruments designed specifically for "on-the-line" service.

They are completely calibrated at the factory to provide a measurement of electrical potentials from 0 to 999.99 volts with an accuracy of 0.01%. No further adjustments or calibration corrections are required by the operator. Stability of the internal reference is guaranteed to stay within specifications for a minimum of six months.

Each instrument, as received from the factory, is ready for immediate use. Connectors are provided on the back of the instrument for signal input, printout, and line voltage. Four control knobs and a pushbutton on the front panel give the operator complete finger-touch command over the functions of the instrument. Range and polarity are automatically selected. Easily read visual indicators present a digital display of the measured value, plus polarity and decimal point.

All circuits, except the power supply, are mounted on plug-in cards that may be inserted or removed by swinging the front panels to either side. The instrument can therefore be completely serviced without removing it from its rack. Periodic re-calibration by Standards personnel is accomplished by a single screwdriver adjustment, also through the front of the instrument.

FIGURE 1.1 - Dana Model 5100 Digital Voltmeter

Every effort has therefore been made to make the DVM as simple to operate and foolproof as possible. At the same time, a basic understanding of the instrument and how it operates will allow the user to gain the full potential of the instrument. A number of the instrument's most important characteristics, including its exceptional isolation (common mode rejection is 1,000,000 to 1), reference voltage stability, high input impedance, and floating printout are the direct result of its internal circuitry. The sum of these characteristics allows the Dana instruments to be used in many applications that previously have been prohibited to DVM's of any type.

The purpose of this manual, then, is both to familiarize the user with the day-to-day operation of the instrument and to provide an insight into the potential new applications to which the instruments may be put.

1.2 ACCESSORIES

Accessory functions may be added to DVM's by slipping appropriate circuit cards into the card guides reserved for that purpose. Four standard accessories are currently available as follows.

Model No.	Functions
0001	Preamplifier
0002	Ohms-DC Converter
0004	Input Filter (4 digit)
0005	Input Filter (5 digit)
0020	AC-DC Converter

The compact design of the Dana DVM's allows all of these various combinations to be incorporated into the same basic package. No outside cables or controls are required.

This manual deals with the basic Digital Voltmeter. Supplementary instructions are provided for operating and servicing the various accessories.

2. SPECIFICATIONS

Series 5000 DVM

Full Scale Voltage Ranges	± 9.0000; ± 99.999; ± 999.99
*Full Scale Ratio Ranges	9.9999; 99.999; 999.99 : 1 (display is "ratio X 10")
DC Voltage Accuracy	Reference accuracy ± 0.01% of reading or ± 1 digit, whichever is greater
DC Ratio Accuracy	± .003% of full scale
Reference Accuracy	Factory set at +25°C to within 20 ppm (0.002%) of Dana secondary standard
Reference Stability (at + 15° to + 35° C)	± 100 ppm (0.01%) for any consecutive six month period
Useful Operating Range	0 to +50°C
*External Reference Voltage	0 to + 11 volts (reduced resolution below 10 volts)
External Reference Input Impedance	20 megohms minimum
Resolution	0.001% of full scale
Sensitivity	100 microvolts
Common Mode Rejection with 1000 ohms unbalanced source	120 db at 60 cps
Input Impedance	Greater than 1000 megohms below 10 volts reference; 10.00 megohms above 10 volts reference
Fixed Balance Time	105 milliseconds
Fixed Balance Time plus Ranging and Polarity Changes (worst case)	135 milliseconds
Measurements/second	8 to 10

Size	5-1/4" rack height
Power Requirement	35 watts; 105 to 125 volts, 50 to 70 cps (50 to 400 cps available on special order)
Standard Features	Voltmeter function Ratiometer function Automatic ranging Polarity indication
Accessory Features	Remote readout Remote programming DC preamplifier Ohms - to DC converter AC - to - DC converter Input Filter
Guarantees	12 months, faulty workmanship or component failure; 18 months, ability of reference voltage to hold within stability specification for any previous six months

*The Dana voltmeters are normally connected for use with positive signals and positive reference voltages; however, any fixed or automatic bipolar combination of polarities is available on special order.

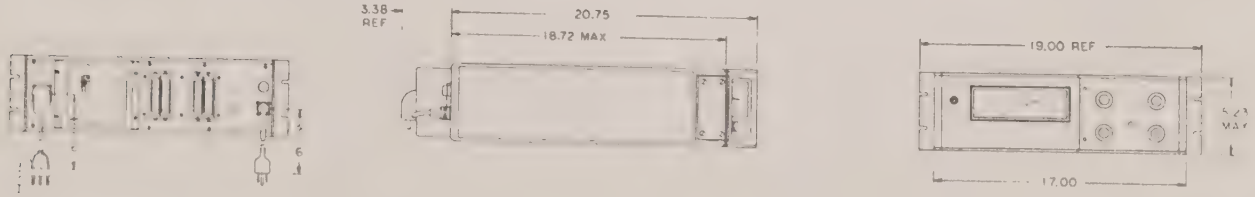

FIGURE 2.1 - Outline Dimensions

3. DESCRIPTION

3.1 GENERAL

The Dana DVM is a precision instrument for measuring electrical potentials in the range zero to 1000 volts. The instrument is wholly automatic. The input is merely connected to the unknown potential and the value is displayed in digital form complete with range and polarity indicators. Measurement is more rapid than the eye can follow.

In addition to the visual display, an electrical output isolated from the signal is provided. The numerical value of the potential in volts is provided in either ten-line decimal or binary coded decimal.

Accuracy is assured by the DVM's ability to measure the potential between the input terminals without causing undue disturbance that may cause the signal to vary from its open circuit value. This is accomplished by a combination of high input impedance and isolation from power line ground. This isolation, the result of Dana's unique box-within-a-box construction, is preserved even when the electrical output drives a printer, by another exclusive feature: PCM isolation. Pulse Code Modulation couples the value of the measurement in incorruptible digital form to the output register.

Reliable operation and long life is assured by the fullest possible use of solid-state components. All high speed switching is by transistor switches. Electromechanical relays are used only for infrequent changes of polarity or range, and these never move on a trial basis.

The instrument uses a null balance potentiometer, the stablest and most accurate of all measurement techniques, to compare the unknown signal with an internal reference voltage. The internal reference voltage is guaranteed to remain stable to 100 ppm for any consecutive six months, starting during the warranty period. If this reference should change, a single adjustment restores the instrument to full accuracy.

The features of inherent accuracy, isolation, reliability, are important in a laboratory instrument, but they are critical in an automatic system. When used as a system component, other features such as programmable range and single measurement upon command are available.

Measurements are extended to microvolts, AC volts and resistance by accessories contained within the small instrument case. No external or additional controls are needed.

The instrument is completely self-contained, calibrated, and ready for use as received from the factory. Power is supplied by a standard 60-cycle 115 AC power line.

3.2 INSTRUMENT CASE

The DVM is contained in a case 17" wide, 5 1/4" high, 18 3/4" deep. This case is designed so that the DVM may be used with screw-on feet as a bench-test instrument or mounted in a standard EIA relay rack. When used in a relay rack, the case is modified by attaching the flanges provided with the instrument and removing the four plastic feet (if required).

All of the electrical inputs and outputs, including the AC power lines, are connected at the rear of the instrument. When mounted in a relay rack, only the front panel is visible. This panel contains all of the indicators and controls required by the operator.

The front panel is divided vertically into two sections. The section on the operator's left carries the Nixie indicating lamps and the AC power switch. The right-hand section carries the operating controls.

The two half-panel sections are mounted as doors, hinged at the instrument handles on either side. The two doors swing open to provide access to virtually the entire circuitry of the DVM. All circuitry is mounted on removable subassemblies, except for the power supplies at the rear of the instrument, and the control circuits are mounted on the doors. The individual circuit cards may be removed through the front-panel opening without removing the instrument from its rack.

3.3 CIRCUIT-CARD SUBASSEMBLIES

All of the subassembly cards are mechanically uniform, each being 4 1/2" by 10 1/2" and mating with identical 31-pin connectors. The connectors stand vertically near the rear of the instrument. Each card is provided with a lever to assist in its removal. A sequence of identifying marks on the cards and on the chassis frame indicates the proper position for each card assembly.

In the event that field servicing is required, it is only necessary to replace the one card which is malfunctioning. Wide tolerances are provided in the design of each subassembly card, so that a card of any given type can be removed from one instrument, or from spare-parts inventory, and immediately placed in another instrument. No adjustments or tests are required before putting the repaired instrument back in use. (See Section 8, Service and Maintenance.)

3.4 INTERNAL ORGANIZATION

There are 27 card locations in the basic case design. Each of these locations is identified, beginning at the operator's left with Number 1 and proceeding, with a uniform distance between centers, to the last card in position, Number 27, on the extreme right.

The basic DVM circuitry occupies the majority of these locations. Another is taken up by the Shield-Guard Interface described below. The remaining locations may be used to accommodate accessories, including AC converter, Filter, Preamplifier, and Ohms Converter.

3.5 SHIELD AND GUARD COMPARTMENTS

A close examination of the case with the doors open will reveal that the cards are contained within two isolated compartments that are electrically isolated from the instrument case. The compartment on the operator's left is designated as the Shield or Output Card Box; the compartment on the right, the Guard or Floating Card Box.

The Guard compartment coincides with the right-hand front-panel door. The Shield compartment coincides with the left-hand door. Cards in the latter section make up the "Indicator Register". The Guard section contains the measuring circuits and accessories. Card Location Number 9 is occupied by the Guard and Shield walls.

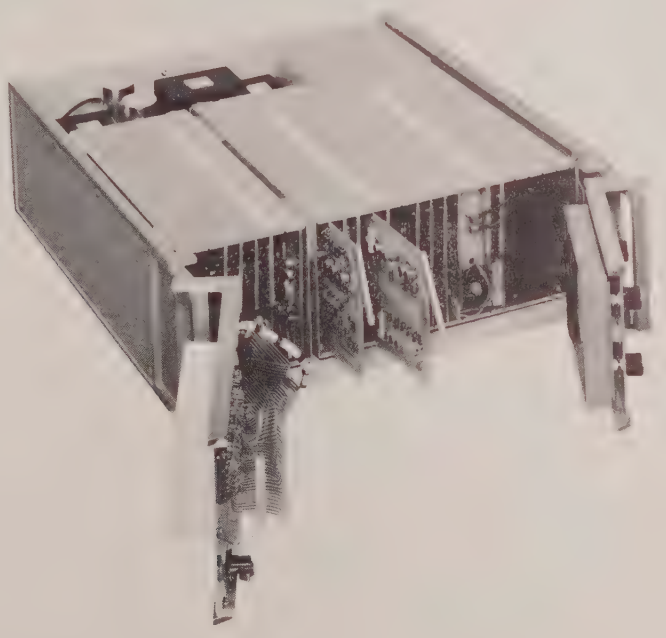

FIGURE 3.1 - Open View of Model 5000 DVM

3.6 CARD LOCATIONS

All Series 5000 DVM's have standard card locations for the various circuit subassemblies. The following table indicates the address of each subassembly card.

Address	Name	Color Code	Part No.
	Indicator Register		
01	Range and Polarity Indicator	These cards depend on the output option selected. See table on opposite page.	
02	Output Decade (10,000's)		
03	Output Decade (1000's)		
04	Output Decade (100's)		
05	Output Decade (10's)		
06	Output Decade (units)		
07	Blank		
08	PCM Demodulator	Black-Orange	401197
09	Shield-Guard Interface		
	Guard Compartment		
10	PCM Modulator	Black-Yellow	400042
11	Range Counter	Black-Green	401199
12	Program Counter	Black-Blue	401202
13	Clock	Brown-Orange	400047
14	Correction Logic	Black-Gray	401201
15	Lower Order Decade	Black-White	401193
16	Lower Order Decade	Black-White	401193
17	Lower Order Decade	Black-White	401193
18	1000 Decade	Brown-Yellow	400045
19	10,000 Decade	Brown-Green	400046
20	Blank		
21	Null Detector	Brown-Blue	400048
22	Internal Reference and Buffer	Brown-Red	400043
23	*Filter	Orange-Orange	400108
24	Blank		
25	*AC Converter (0020)	Red-Yellow	400032
26	*Preamplifier (0001)	Orange-Blue	400112
27	*Ohms Converter (0002)	Brown-White	400055

*Optional Accessories

The location of the cards in the Indicator Register corresponds with the six Nixie indicators on the left-hand panel door. The card on the operator's extreme left corresponds with the extreme left indicator which shows polarity. The same card, No. 1, also controls the neon indicators for decimal-point display.

Connection between the cards and the Nixie indicators is by individual Flex-print cables. The cable mates with a connector on the front of each indicator card.

Part Numbers for Standard Output Options

	Address 01 Range & Polarity Indicator		Address 02, 03, 04, 05, 06 Output Decades	
Output Option	Color Code	Part No.	Color Code	Part No.
A1	Black-Brown	401203	Black-Red	401192
B1	Red-Orange	400096	Red-Brown	400094
B2	Orange-Black	400104	Red-Gray	400097
B3	Red-Orange	400096	Red-Brown	400094
B4	Orange-Black	400104	Red-Gray	400097
C1	Red-Black	400093	Brown-Gray	400089
C2	Orange-Brown	400105	Red-Blue	400099
C3	Red-Black	400093	Brown-Gray	400089
C4	Orange-Brown	400105	Red-Blue	400099
D1	Orange-Yellow	400118	Black-Red	401192

3.7 CARD FUNCTIONS

Section 7, Theory of Operations, describes the operation of the instrument in terms of its various subassemblies. The function of each subassembly card may, therefore, be derived by referring to the appropriate paragraphs in the Theory of Operation section.

STANDARDS LABORATORY CALIBRATION PROCEDURE FOR DANA AC CONVERTER, MODEL 0020

Equipment Required:

AC signal source, 50 cps to 10 kc, 0-500.00 volts RMS ± 0.03% with distortion of less than 0.03%.

Dana DVM Extender Card assembly part #400035 and converter input extender cable, (supplied with extender kit part #400913).

1.0 With the DVM power OFF, insert the converter with extender card, support bracket, and extender cable into the DVM. The door should be braced far enough open to keep it from shorting against the back of the extended unit.

1.1 Turn the power on and allow the voltmeter to warm up 10-20 minutes.

2.0 Threshold Adjustment

2.1 Place the Function switch to AC volts, "Range" to 10, and "Mode" to "Periodic".

2.2 Set DVM to its 10 volt range. Set the Input accurately to 10 millivolts at 400 cps. Adjust R1 to read 10.0 mv.

3.0 AC Calibration

For optimum performance, the following procedure should be followed in the exact order described. Many adjustments are interacting and, if the order is changed, it will be impossible to complete the calibration. For all of the following steps, the meter should be connected to the AC source as in Figure 1.

3.1 10 Volt Range

3.1.1 Place the "Range Selector" to "10", apply 400 cps at 9.0000 ± 0.0027 volts RMS to the meter. Retain this voltage level for each frequency called for in the 10 volt range.

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4. INSPECTION AND INSTALLATION

4.1 UNPACKING

The digital voltmeters are shipped in a completely assembled state, ready for immediate use. Carefully remove the instrument from its shipping carton. Inspect for dents, scratches, or other obvious evidence of physical damage. This should be done while the carrier's agent is still present.

Each instrument is shipped with input cables, mating connectors and other loose parts. These are contained in a closed compartment within the shipping carton. Care should be taken so that they are not lost in the unpacking process. A list of this material follows.

Power Line Cable
Signal Input Cable Assembly
Remote Output Connectors
Calibration Cord
Rack Mounting Flanges

4.2 PHYSICAL INSPECTION

Examine the Nixie and neon indicator bulbs. Check all of the switches. Rotary controls on the front panel should turn freely.

Turn the two knurled knobs on the right-hand door a half turn, and open the door. Release the latch inside the lower-right corner of the left-hand door, and open this door. Both doors should swing easily on their hinges. The inner cover plate across the center section of the instrument is held in place by dimples on the top and bottom flanges. Remove the plate if necessary to inspect cards. (Isolation of the measurement circuits requires that the plate be in place and both doors closed during operation.) Check the printed-circuit cables connecting the Nixie-bulb sockets with their mating circuit cards. There should be no kinks or scratches on these cables. Be sure they are securely seated in their connectors.

Remove each circuit card, one at a time using the lever provided on the card to withdraw it from its rear connector. Inspect for loose or damaged components and replace, noting the color code indicating the proper location. The cards are designed to fit the rear connectors quite snugly and must be depressed firmly when replacing.

Any faults uncovered by this physical inspection should immediately be reported to both Dana and the carrier.

4.3 INSTALLATION

If the unit is to be used as a bench-top instrument, it is shipped ready for use. Power, input and output cables attach as outlined below.

If the unit is to be rack mounted, the mounting brackets (shipped with the instrument) must be installed. Use the screws provided to install the brackets. If necessary, the four plastic feet can be removed. Once the power line and input and output cables have been attached, all future servicing and checkout of the instrument may be made through the front of the unit without removing it from its rack (except for power supply assembly).

4.4 INPUT CONNECTIONS

The power line supplied with the instrument is a standard three-conductor cable terminating with a standard three-connector wall plug. At the instrument, the power line plugs into a three pin connector. If it is required that the instrument be wired into a system power supply, the connector leads may be unsoldered and the new conductors attached to the three terminals as follows:

Connector	Terminal	
J301	A	Hot (black)
J301	B	Neutral (white)
J301	C	Ground (green)

The input cables plug into the instrument through a 17-pin aircraft-type connector (Cannon 20-29), with most of the pins being taken up with an annular brass guard that is soldered to the Signal Common shield (input guard). The size and bulk of this connector is an important factor in maintaining the isolation of the instrument. Conventional jack-type input connectors have been found inadequate in maintaining the high level of common-mode-rejection performance specified. The input connections are made as follows:

Connector	Terminal	Function
J201	A to M	Guard
J201	N	External Reference
J201	P*	Current +
J201	R	Volts Common, Sense -
J201	S	Volts Input, Sense +
J201	T*	Current -

*P and T are used only with instruments equipped with ohmmeter accessory.

Figure 4.2 illustrates the color coding and function of the input cable assembly terminations. It is important that these leads be used properly if the full capability of the DVM is to be realized. For all standard functions except ohms, the input leads should be connected as follows (refer to Figure 4.1).

Volts Input

This lead should always be connected to the side of the test voltage farthest from ground potential regardless of signal polarity.

Volts Common

Connect to the side of the test voltage closest to ground potential.

Guard

The guard must be connected directly to any interference signal which may be present and is common to both inputs (Common Mode Voltage). In many cases, this condition is satisfied by connecting the guard to "volts common" at the source.

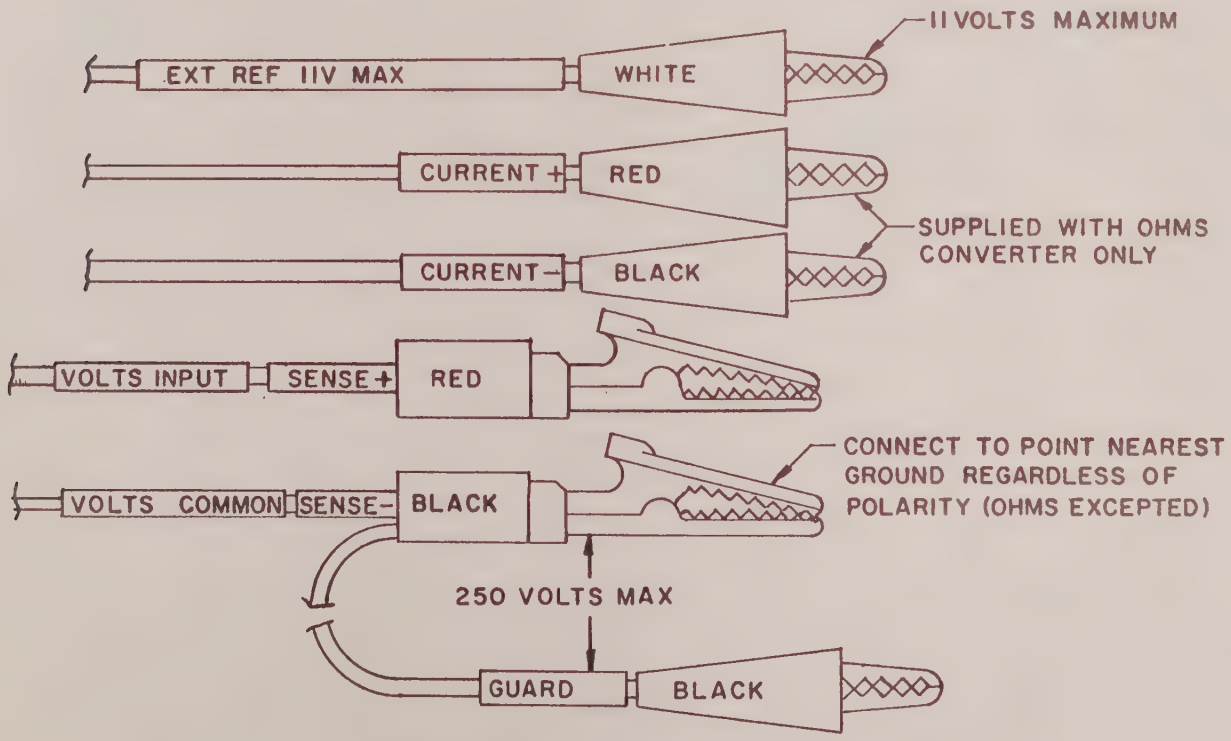

FIGURE 4.1 - DVM Input Cable

External Reference

This lead is connected to the external reference supply when making voltage ratio measurements. Although the reference input circuit is fused (fuse is located on the front of the internal reference and buffer board - address #22), care should be taken to avoid exceeding the 11 volt rating.

Current Leads

These leads are used in conjunction with an ohms converter accessory. A complete procedure for making accurate resistance measurements is supplied in the ohms converter manual.

4.5 ELECTRICAL OUTPUTS

The Digital Voltmeters may be internally wired at the factory to produce a variety of electrical output signals. These in turn may be used to drive a wide range of printout and readout devices. The specific signal and application will have been specified by the user at the time that the instrument was purchased. The DVM's are normally supplied with a 10-line decimal output (Option A1), unless an alternate BCD output is specified.

Output option designations and connector wiring guides for standard options are described on the following pages.

OUTPUT OPTIONS

Option	Description	Connector Table	Logic "1"	Logic "0"
A1	10 Line	I	0 volts 20 ma in	+70 volts 0 current
B1	BCD 1-2-4-8	II	+18 volts 5 K	+0.5 volts 10 ma in
B2*	BCD 1-2-4-8	II	+0.5 volts 10 ma in	+18 volts 5 K
B3*	BCD 1-2-4-8	II	0 volts 5 K	-17.5 volts 10 ma in
B4*	BCD 1-2-4-8	II	-17.5 volts 10 ma in	0 volts 5 K
C1	BCD 1-2-2-4	II	+18 volts 5 K	+0.5 volts 10 ma in
C2*	BCD 1-2-2-4	II	+0.5 volts 10 ma in	+18 volts 5 K
C3*	BCD 1-2-2-4	II	0 volts 5 K	-17.5 volts 10 ma in
C4*	BCD 1-2-2-4	II	-17.5 volts 10 ma in	0 volts 5 K
D1*	(Decade output BCD 1-2-4-8)	II	+5 volts 0.25 ma out	-2 volts 2 ma in
	(Range & Polarity BCD 1-2-4-8)	II	+5 volts 0.25 ma out	0 volts 2 ma in
	(Decade Output 10 Line)	III	0 volts 20 ma in	+70 volts 0 current

-Reference: 0.5 volts, positive with respect to least negative -BCD level.
+Reference: 0.5 volts, negative with respect to least positive +BCD level.

Print Command: 100 microsecond positive going pulse; rise time 1 microsecond. 0 to +18 volts for options A1, B1, B2, C1, C2, D1 and -18 to 0 volts for options B3, B4, C3, and C4.

*Extra Cost Option

TABLE I
Output Option A1
Ten-Line Decimal Pin Connections
J101A, J101B, J102A, J102B (Amphenol 57-20500)

Output	Connector	Terminal (s)
Units (0-9)	J-101A	26-35
Tens (00-90)	J-101B	1-10
Hundreds (000-900)	J-101B	25-16
Thousands (0000-9000)	J-101B	26-35
Ten Thousands	J-102A	1-10
Plus Polarity	J-101A	24
Minus Polarity	J-101A	23
AC Voltage	J-101A	25
K Ohms	J-101A	15
1-volt Range	J-101A	6
10-volt Range	J-101A	5
100-volt Range	J-101A	4
1000-volt Range	J-101A	3
Print Command	J-101A	49
Commons (any one)	J-101A	39, 41, 44
	J-102B	48, 49, 50

TABLE II
Output Option B, C, and D
BCD Pin Connections
J-101* (Amphenol 57-20500)

	X_1	X_2	X_3	X_4
For Any Four Bit Code	1	2	4	8
	1	2	2	4
Units	5	6	30	31
Tens	7	8	32	33
Hundreds	9	10	34	35
Thousand	11	12	36	37
Ten Thousands	13	14	38	39
Range	1	2	26	27
Sign & Function	3	4	28	29

-Reference 24
+Reference 25
Common 50
-Print Command 23
+Print Command 48

*J-101B for D1 Option

TABLE III
Ten-Line Decimal Pin Connections
(Option D)
J-102-B (Amphenol 57-20500)

Output	Connector	Terminal (s)
Units 0-9	J-102-B	10-1
Tens 00-90	J-102-B	25-16
Hundreds 000-900	J-102-B	35-26
Thousands 0000-9000	J-102-B	50-41
Ten Thousands 00000-90000	J-102-B	40-36, 15-11

TABLE IV

Function and Range Codes

Function	Code** (Series 4000 & 5000)	Range	Code** (Series 4000)	Code** (Series 5000)
DC+	+	1000	1	2
DC-	-	100	2	3
AC	1	10	3	4
K Ohms	2	1	4	5

** See Truth Table (TABLE V) For BCD Codes

TABLE V

Truth Table for Dana DVM BCD Outputs

Decimal Number or Symbol	1-2-2-4 Code All "C" Options				1-2-4-8 Code All "B" Options And D-1 Option			
	(1) X_1	(2) X_2	(2) X_3	(4) X_4	(1) X_1	(2) X_2	(4) X_3	(8) X_4
0	0	0	0	0	0	0	0	0
1	1	0	0	0	1	0	0	0
2	0	1	0	0	0	1	0	0
3	1	1	0	0	1	1	0	0
4	0	1	1	0	0	0	1	0
5	1	1	1	0	1	0	1	0
6	0	0	1	1	0	1	1	0
7	1	0	1	1	1	1	1	0
8	0	1	1	1	0	0	0	1
9	1	1	1	1	1	0	0	1
-	1	0	0	1	1	1	0	1
+	0	0	0	1	0	1	0	1

TABLE VI

Compatibility Dana Electrical Output Options & H-P Printers

DANA OPTION	H-P PRINTER & OPTIONS
A1	561B
C1	562A Option 12
C1	562A Options 21*, 30, 32
C2	562A Options 24*, 30, 32
C3	562A Options 21*, 30, 32
C4	562A Options 24*, 30, 32
B1	562A Options 22*, 30, 32
B2	562A Options 23*, 30, 32
B3	562A Options 22*, 30, 32
B4	562A Options 23*, 30, 32
D1	562A Options 22*, 30, 32
	561B (Decades Only - Special Cable Required)

*7 Column Boards Required

TABLE VII

Print Format for H-P 561B or H-P 562A

Column:	11	10	9	8	7	6	5	4	3	2	1
					100 Thousand	Ten Thousand	Thousands	Tens	Units	Symbol	Range

Range: Reads as a negative power (See Table IV)

Symbol:			
+	Prints	Blank (562A) Zero (561B)	
-	Prints	-	(562A, 561B)
AC	Prints	1	(562A, 561B)
K Ohms	Prints	2	(562A, 561B)

Examples:			
+104.32 volts DC Prints	10432 ?	(562A)	
	1043202	(561B)	
-10.432 volts DC Prints	10432-3	(562A, 561B)	
104.32 volts AC Prints	1043212	(562A, 561B)	
104.32 K Ohms Prints	1043222	(562A, 561B)	

4.6 REMOTE PROGRAMMING

When a Dana DVM is used in an automatic checkout system, it may be desirable to remotely control function or range or both. The programming option provides this capability. If the programming option is installed, remote programming is operative when the function and/or range switch is in the "remote" position. It is possible to remotely program function and for range selection to be manual or automatic if so selected by the front panel switch. Likewise, function may be manually selected and range programmed, if desired.

Any function except preamplifier may be selected by remote programming. Because of the extreme sensitivity of the preamplifier, it cannot be remotely programmed.

Remote programming requires the addition of two circuit cards—one in the guard compartment and one in the output compartment—even so, it is still possible to install three optional accessories (normally the preamplifier would be omitted).

Programming Drive

Remote Range and Function selection is accomplished by switch closures in a BCD Code as follows.

Function			Range		
Bit 1	Bit 2		Bit 3	Bit 4	
0	0	DC Volts	0	0	1000
0	1	AC Volts	0	1	100
1	0	K Ohms	1	0	10
1	1	Filter	1	1	1

Input Connections

Connections for remote programming are made through an Amphenol 126-013 Miniature Hexagon Connector. This connector is provided with the programming option. Connections are shown below.

A - Remote Program Bit 1 Switch Closure
B - Read Command Input Switch Closure
C - Remote Program Bit 3 Switch Closure
D - Remote Common
E - Remote Common
F - Remote Common

table continued

H - Remote Program Bit 2 Switch Closure
J - Read Command Input Pulse
K - Remote Program Bit 4 Switch Closure

Command Signal	Electrical Values
Pulse*	6 volts minimum 20 volts maximum 6×10^6 volts/sec minimum rise time 10 us minimum width
Contact Closure*	6 volts (when open) (Generated within instrument)

*Operates with or without remote programming option.

5. CHECKOUT AND OPERATION

5.1 CHECKOUT PROCEDURE

The purpose of the checkout procedure is to verify that the instrument is in an operational condition. The simple tests described in this section are meant only to evaluate the gross characteristics of the instrument. They should not be confused with the more refined recalibration procedure described in Section 6.

Each instrument is completely checked out before it leaves the factory. Consequently, if it should fail any of these trials, it is certain that damage has occurred during shipment. No attempt at field servicing should be made. Instead, notify immediately both the carrier and the Dana representative.

The test equipment needed for the checkout procedure is a set of batteries (or DC power supplies) capable of producing voltages in each of the instrument's ranges plus a 3-terminal potentiometer or resistance box capable of dividing these voltages.

5.2 POWER ON

Turn the Reading Mode switch to the Periodic position. Rotate the Manual Threshold control to the extreme clockwise position and do not adjust again until the test for manual threshold is made. Switch the Range Control to Automatic. Turn the Function Control to the Test position. (Early models, turn to Test A position)

FIGURE 5.1 - Model 5100 Operating Controls

Insert the power-line plug into a wall receptacle or other source of 115 volt AC power and connect to the instrument. Turn the Power Switch on the left-hand front panel door to the "on" position. A number should appear on the Nixie display. This number should correspond, within ± ten digits of the setting shown as a first entry to Test A (see footnote page 5.5 on Test A and Test B) on the Calibration Log attached to the inside of the front panel door.

5.3 ZERO POINT

Plug in the Input Cable Connector at the back of the instrument. Turn the Function Control to read Volts. Short the two input leads. The visual display should read 0.0000.

With the leads still shorted, turn the Range Control to the 0-1000 volt range. The visual display should read 0000.0. Turn the Range Control to the 100-volt range. The display should now read 000.00. Continue the test for the remaining range, noting the position of the decimal point in each case. The polarity symbol may be either plus or minus.

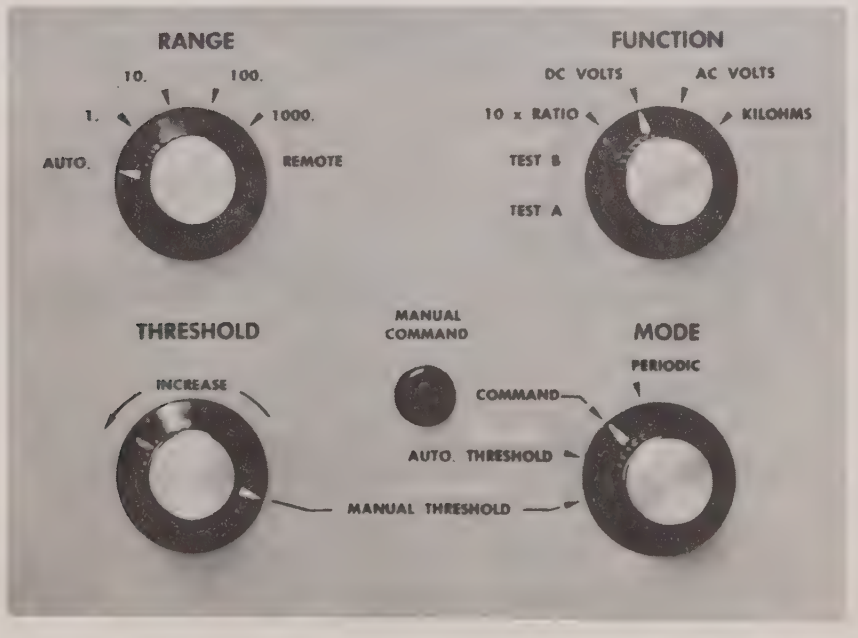

FIGURE 5.2 - Model 5000 Operating Controls

5.4 POLARITY TESTS

To test the ability of the instrument to detect and display polarity, connect the leads to the batteries to obtain either a plus or minus polarity, then reverse the leads. The same number (± 1 digit) should be reproduced, but with an opposite sign. Repeat the test for each range, using battery combinations that are between 10% and 100% of the full scale of the range being tested.

5.5 RANGE CHANGES

Switch the Range Control to Automatic. Connect the leads to the various battery combinations used above. Notice whether the instrument automatically adjusts to the optimum range. Next, connect the leads to the battery combination used for testing the 0-10 volts range and note the reading. Move the Range Control to the 100 and 1000 volt positions. The number should move progressively to the right with each range change. Repeat the experiment with the battery combinations used for the 100-volt and 1000-volt ranges.

Note: The 1.0 volt range position on Series 5000 instruments is not operative in the DC volts function, but is used when an Ohms or AC Converter is added.

5.6 RANGE TRANSFER POINTS

Connect a variable resistor or potentiometer into the battery circuit. The objective is to attenuate the test voltage past the automatic range transfer points. (Up-ranging occurs at 99.99% of full-scale; down-ranging occurs at 9.909% of full-scale.) Turn the Range Control to the Automatic position. Using the most appropriate battery combinations for each transfer point, slowly adjust the input signal to test both the up-range and down-range transfers.

5.7 TRACKING AND THRESHOLD CONTROL

Turn the Reading-Mode control to the Manual Threshold tracking position. Using one of the battery combinations, test the stability of the reading. New readings should occur only when the voltage input is changed. Slowly adjust the voltage, allowing the instrument to track its progress. Continue through the range-change points. These should correspond with those detected above.

Move the Manual Threshold control to approximately a mid-point position. Slowly change the input signal. No new readings should occur until a change equivalent to approximately five digits has been made. When this "threshold" has been exceeded, a new reading will occur. The second reading will in turn remain fixed until another five-digit span has been tracked.

The Manual Threshold control has a full-scale of approximately 10 digits. Repeat the threshold test at full scale and at several intermediate points.

5.8 AUTOMATIC THRESHOLD

Turn the Reading Mode control to Automatic Threshold. Twist the potentiometer knob rapidly back and forth to simulate noise. The reading should remain stable so long as the "noise" is present, then switch to a new reading as soon as the "noise" has stopped.

5.9 COMMON MODE REJECTION

To test the Common Mode Rejection, connect the DVM as shown in Figure 5.3. The signal should be a battery of less than 10 volts and the common mode source a signal generator (usually with step up transformer) set for 100 volts peak at 60 cps. Switching the common mode voltage in and out should not affect the reading by more than $\pm$ 1 digit. If necessary, adjust E_s slightly to insure that the value of E_s does not disagree with the reading by a fraction of a digit.

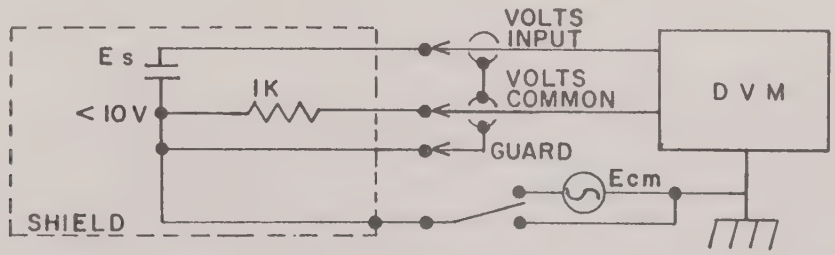

FIGURE 5.3 - Common Mode Rejection Test

5.10 RATIO OPERATION

Place the function switch in the "Ratio x 10" position. Connect an external reference supply (0 to 11 volts with full resolution above 10 volts) between the DVM "Ext Ref" and "Volts Common" terminals, and a second voltage between "Volts Input" and "Volts Common" (both inputs positive with respect to Common). The DVM should display a reading equal to 10 times the ratio of Signal Voltage/Reference Voltage. If the instrument fails to function, check the fuse on the reference buffer card (card position #22).

In applications where it is not feasible to connect both signals to a common point, a differential amplifier such as the Dana Model 2000 must be used (converting the four wire input to the three wire system of the DVM).

5.11 OPERATING CONTROLS

The checkout procedures have, in effect, "walked the instrument through its paces". However, a review of the operating controls and their functions would be helpful.

The Function Control allows the operator to select among the various primary and auxiliary functions built into the instrument. When turned to "DC Volts", the instrument operates from its Internal Reference, and presents a digital display of voltage values. When turned to "Ratio X10", the instrument compares the signal input with an External Reference voltage and presents a reading equal to 10 times the ratio of the two voltages.

The Test A* position is a self-check on the digital portions of the instrument. In effect, the instrument measures the output of its Internal Reference before it has been amplified by the Buffer Amplifier to an exact 11.0000 volts. The precise value will vary for each instrument, but should be stable within ± ten digits of the factory-determined voltage written on the calibration log for this reading. If there is a gross change in the Test A reading, it indicates a major malfunction in the instrument which requires immediate repair. If there is a slight variation of more than two digits, it indicates that the instrument is probably off calibration; however, a stable Test A reading does not necessarily mean that the instrument is in calibration. This can be determined only by the procedure outlined in Section 6. Test A should be used only as a quick check on the basic operability of the instrument, not its accuracy.

Test B*, on the other hand, is used to monitor the long-term stability of the Internal Reference, as part of the recalibration procedure. Again, a Test B reading that remains stable between calibrations does not necessarily indicate that the instrument is in calibration. Stability is determined by the difference in the Test B reading following each recalibration. The Test B voltage is, in effect, a sensitive measure of the setting of the calibration vernier in the Internal Reference circuit.

The remaining positions on this control apply only when auxiliary function, such as an ohmmeter, AC-DC conversion, or preamplifier are included.

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*Early Model 5000 instruments provided separate Test A and Test B positions on the front panel. Later models have a single "test" position corresponding to Test A. To perform Test B on these models, the front panel mode switch is left on the test position and a spring loaded toggle switch on the front of the Reference Buffer board is depressed. The Reference Buffer is located behind the right panel section in address #22.

The Range Control is generally left in the Automatic position, since the instrument will then automatically select the optimum range for any measurement. The remaining positions act as a manual override on the automatic selection. (See Section 5.5 on significance of 1.0 volt range position.) The off-setting of the up-range and down-range transfer points provides a large measure of stability when the readings are near the transfer points. However, under certain conditions, it may be desirable to keep the instrument on a particular range, even when the accuracy of the reading would be enhanced by dropping to a lower range.

The Reading Mode Control provides two basic choices: on-command or tracking.

The "Command" position calls for a single reading in response to either a push-button or a remote signal. The reading remains on the visual display until a second command is given. The "Periodic" position activates an internal clock which provides a command signal approximately two times per second.

In the Tracking Mode, the instrument continuously monitors the input signal, presenting a new reading each time the signal changes beyond a fixed value. Normally, this "threshold" is one digit. In the "Manual Threshold" tracking mode, the minimum signal-change required for a new reading is adjusted by the Manual Threshold Control to any value between one and ten digits. Once the threshold has been passed, the instrument takes a new reading at full specification accuracy. The objective is to set the manual threshold at a value slightly in excess of any extraneous noise on the signal.

In the "Automatic Threshold" tracking mode, the threshold automatically compensates for any amount of noise that might be on the signal. The instrument ignores AC noise of 2.5 cps frequency or higher, calling for a new reading only when the signal-plus-noise envelope has departed from the previous reading by more than one digit. This is accomplished by a simple adaptation of existing circuitry in the DVM; specifically, the timing circuits associated with the periodic mode, the null detector, and associated storage Flip Flops. At the end of each measuring sequence, the timing circuit (ramp generator) is set to zero and the null detector compares the stored reading with the input signal. If only an up or down pulse occurs during the preset time period, a new reading will be commanded, but if one or more up and down pulses occur during the observation period, the timer is reset to zero and the operation is repeated.

The Filter switch* is part of the Threshold assembly and is actuated by snapping the Threshold control in and out. The control knob is clearly marked "pull for Filter".

The Power Switch is the only remaining front panel control. It should be in the "off" position when the instrument is connected to its power source. Since semi-conductors are used in all of the measurement signals, no appreciable warm-up time

is required. The power switch may be turned "on" and the instrument used immediately. (Full accuracy realized in a few moments)

*Early instruments are not equipped with this feature but may be modified at the factory if the filter option is required.

6. RECALIBRATION

6.1 RECALIBRATION SCHEDULE

The Internal Reference Voltage of the Dana Series 5000 DVM is guaranteed to vary or drift less than 100 ppm (0.01%) during any consecutive six months, starting within the guarantee period.

The "linearity" of the instrument, defined as its ability to produce digital data that bears an exact linear relationship to either the Internal Reference Voltage or an external reference, is calibrated at the factory for the life of the instrument. No subsequent adjustments are required, nor are any provided.

The result is a sharp reduction in both the frequency and the complexity of recalibration, compared to other instruments of this type. However, the user's company policy may require monthly or other more frequent calibration checks as a matter of routine. Moreover, the user may wish to make a number of checks during the first few months that the instrument is in service in order to obtain assurance that the DVM is meeting its stability specifications.

A unique feature of the Dana 5000 DVM is that the precise setting of the Internal Reference calibration vernier may be determined by setting the controls to perform Test B (see footnote on page 5.5). The quantitized value may be read on the Nixie display and recorded on a calibration log provided on the instrument. It is therefore possible to obtain an exact historical record of the instrument's stability performance. This in turn can be used to establish recalibration schedules that are based on the actual requirements of the instrument.

6.2 RECALIBRATION PROCEDURE

The Internal Reference is the only portion of the Dana DVM that requires periodic adjustment. All other variables, including zero point, decade dividers, and range ratios, are calibrated at the factory and fixed for the life of the instrument.

The Internal Reference is calibrated by a single screwdriver adjustment through an opening behind the right-hand front-panel door. A seal may be used to close off the hole to prevent unauthorized changes in the calibration setting.

In general, all recalibrations should be conducted by authorized Standards personnel. Also, for optimum accuracy, the Dana DVM should always be calibrated against a voltage standard that is traceable to the National Bureau of Standards.

First step is to remove the intercard connection and insert the recalibration test leads into the socket provided on the front of the Voltage Divider (10,000) Card (Location 19). The voltage across these two leads is the output of the Buffer Amplifier, and the objective of the recalibration procedure is to adjust this voltage to exactly 11.0000 volts.

The recommended circuit for this purpose is shown in Figure 6.1. The secondary standard and voltage divider should have an assured accuracy of at least one order of magnitude greater than that of the DVM, or 0.001%. The galvanometer should be of comparable precision. Set the voltage divider so that the 11.000 volts from the internal reference would be divided to a voltage exactly equal to the secondary standard if the DVM were in calibration. Adjust the Internal Reference vernier, located on the front of the Reference Buffer card (card position #22), until an exact null balance is achieved.

The final step is to remove the test leads and set the instrument to the Test B mode. (See footnote Page 5.5) The new setting of the calibration vernier will be displayed in volts on the instrument readout. Write the date and setting on the calibration log located immediately behind the left front panel section. Figure 6.2 shows a typical calibration log for an instrument that has been in service for one year. Observing the Test B readings, it would appear that the instrument exhibited considerable drift; however, this is not the case since Test B is effectively a large magnification of the calibration vernier setting. The sample instrument actually shifted less than 50 ppm during the one-year period. The actual drift is determined by comparing the difference between the Test B readings in millivolts with the factory notation on the Calibration Log indicating the number of millivolts variance allowable within the 100 ppm stability specification (e.g. 100 ppm = 115 millivolts).

The above notation is unique for each instrument as is the resolution of the calibration adjustment. Regarding the latter, the resolution of the calibration control should not be confused with the number of digits change in the Test B reading. Reference must always be made to the change in millivolts (last two digits of Test B reading may be disregarded if desired). The actual resolution of the calibration control is sufficient to set the reference to within 20 ppm of a secondary standard. Experience has indicated that the calibration drift is not linear with time. It is not possible, therefore, to extrapolate the six-month stability from the data gained during the first few recalibrations. Dana's guarantee is that during any six consecutive months, the total departure from any previous setting will be within the 100 ppm limit.

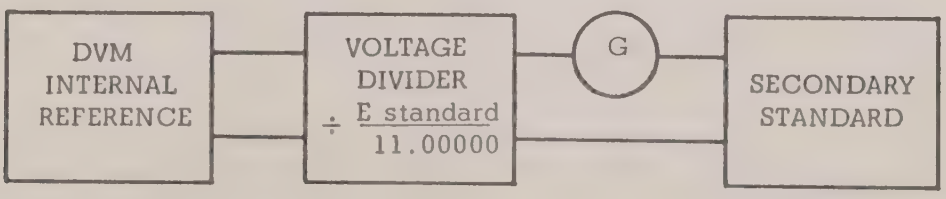


FIGURE 6.1 – Recalibration Circuit

CALIBRATION LOG

100 ppm = 115 MV SERIAL NO. 031131

DATE	TEST VOLTAGE (A) VOLTS	TEST VOLTAGE (B) VOLTS	CALIBRATED BY
1/1/62	6.1840	5.9445	Dana Labs
1/15/62	6.1840	5.9315	Using Facil.
2/15/62	6.1843	5.9435	Using Facil.
3/15/62	6.1837	5.9722	Using Facil.
4/15/62	6.1837	5.9690	Using Facil.
7/15/62	6.1841	5.9957	Using Facil.
10/15/62	6.1845	6.0040	Using Facil.
1/1/63	6.1841	5.9830	Using Facil.

FIGURE 6.2 - Typical Calibration Log

At the same time that the Test B reading is recorded, it is advisable to read and record the Test A value. As noted in Section 5.10, the Test A reading is only a rough check on the operation of the instrument. However, it should remain stable within ten digits so long as the Internal Reference stays within its stability specifications.

6.3 LINEARITY CHECKS

No adjustments are required or provided for calibration of linearity. However, the user may want to check the linearity of the instrument from time to time in order to satisfy himself that there has been no change in the component values.

The recommended circuit for this test is shown in Figure 6.3 (the precision divider should have a total series resistance of 2.5K or less). The instrument is operated in the Ratiometer mode to eliminate any variables due to instabilities in the power source. The comparison is between the settings of the precision voltage divider and the DVM. These should agree within 0.01% at all settings between 0.0000 and 9.9999. By using appropriate power sources, the linearity may be checked on all three ranges; however, care must be taken to avoid loading due to the 10 megohm input attenuator.

6.4 LOCATION FOR RECALIBRATION TESTS

The usual procedure is to remove the instrument from its rack or laboratory-bench location and take it to a Standards Laboratory for the recalibration check.

However, since the entire procedure is performed through the front-panel opening, it is possible to recalibrate the instrument without removing it from its rack.

A third option, of particular value to installations containing a number of DVM's, is to remove only the Internal Reference card from the instrument, replacing it immediately with a calibrated Internal Reference card from an equivalent DVM located in the Standards Laboratory. A feature of the Dana digital voltmeters is that all cards are interchangeable between instruments, including the Internal Reference. It is therefore possible to perform all of the calibration checks on a DVM kept at the Standards Laboratory, reducing the recalibration of instruments on-the-line to the simple substitution of this single card.

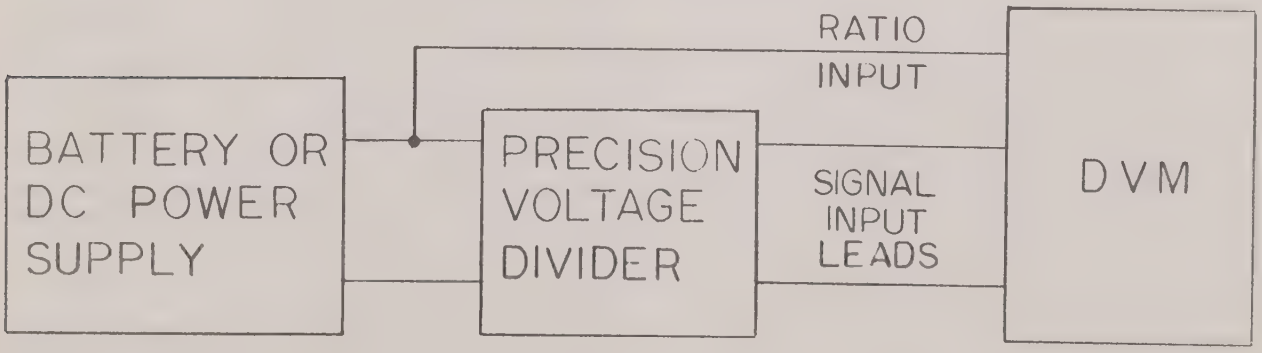


FIGURE 6.3 - Circuit For Testing Linearity

7. THEORY OF OPERATION

7.1 GENERAL THEORY

To obtain its exceptionally high degree of accuracy and resolution, the Dana DVM uses the classic potentiometric method of measuring voltage. A known comparison voltage is brought to an exact null balance with the unknown signal voltage. The readout, visual or printed, is a digital representation of the value of the comparison voltage required to balance the input.

Six basic elements are required in the design of a practical instrument to achieve this result:

1. A reference voltage source that must be accurate, stable, and traceable to the Standard Volt at the U.S. Bureau of Standards.
2. A buffered voltage, standardized to the reference voltage and capable of driving load currents.
3. A voltage divider that must be digitally controllable in 99,999 uniform steps. The input to this voltage divider is the buffered voltage; the output is a comparison voltage.
4. A null detector to compare the unknown signal with the comparison voltage.
5. An electrical output which is isolated from the measuring circuits, so that output devices can be operated without introducing ground loops.
6. A range divider that will allow the instrument to measure, with full accuracy, signal voltages that are one or more orders of magnitude larger than the full-scale comparison voltage.

Figure 7.1, which is a general block diagram of the basic digital voltmeter, reveals the design elements used to achieve these results.

The Internal Reference (or External Reference), Reference Buffer, and Comparison Voltage Divider comprise the source of Comparison Voltage.

The Null Detector, Program Control, and Switch Register provide the means for detecting the difference between the Comparison Voltage and Input Signal, plus the control circuits for changing the Comparison Voltage Divider to achieve a null balance.

The Input Range Divider allows the instrument to measure input voltages from 0-1000 volts.

The two PCM Modulator-Demodulators telemeter information from the isolated measurement circuits to the readout circuits. This allows the instrument to be connected to grounded or floating printout devices without incurring common-mode errors due to ground loops.

Each of these subassemblies is described later in this section, but first an overall description of the instrument's operation will help to put the elements in perspective.

To achieve balance, the Comparison Voltage and Input Signal must be of the same sense (polarity), relative to a common terminal. This is accomplished by the Automatic Polarity Switch, acting in response to a signal from the Null Detector. The state of this switch is indicated by the polarity on the Visual Readout and a polarity signal on the printout.

The Comparison Voltage is generated by the Reference Buffer and Comparison Voltage Divider. The digital presentation is derived by monitoring the division ratio required to achieve a balanced condition. If the Internal Reference is used, the output of the Buffer Amplifier is exactly 11.000 volts, plus or minus 20 parts per million, as calibrated at the factory by a Dana secondary standard traceable to the U.S. Bureau of Standards. If an External Reference is used, the output of the Reference Buffer is 110.0% of the External Reference Voltage.

The Reference Buffer is essentially an extremely accurate DC amplifier, operated in a negative feedback potentiometric mode. The Internal Reference is part of the feed-back network, and includes a carefully selected, preaged Zener diode. By using the Reference Buffer as a preregulator for the Zener circuit, the diode is isolated from changes in AC line voltage, thus avoiding the instabilities associated with conventional preregulators. The Zener circuit essentially has a zero temperature coefficient within the specification operating range; it therefore does not require an oven or thermostat, nor does the instrument require any appreciable warm-up time.

Since the Internal Reference is part of the feedback network, it acts as a true reference source; it controls the output of the Reference Buffer, but no load current is drawn from it. The Reference Buffer, on the other hand, is an accurate source of drive current for the Comparison Voltage Divider; its source impedance is considerably less than 1 ohm. These high-input, low-output impedance characteristics also make the amplifier ideally suited as a buffer for external references, such as standard-cell batteries.

The full scale of the Comparison Voltage, when using the Internal Reference, is 10.000 Volts; therefore, when the instrument is on the 10-volt range, the Comparison Voltage is balanced directly against the Input signal. When the instrument is on the 100-volt or 1000-volt ranges, the input signal is reduced to 10-to-1 and 100-to-1 by the Input Range Divider. The state of the range divider is selected automatically by the Program Control and indicated by the location of the decimal point on the visual display and remote printout.

The effect of the Range Divider is to provide a full-scale signal voltage that is identical with the full scale of the comparison voltage. On balance, then, the N value of the Comparison Voltage, as determined by the Comparison Voltage Divider, will equal the digital value of the input signal in terms of volts.

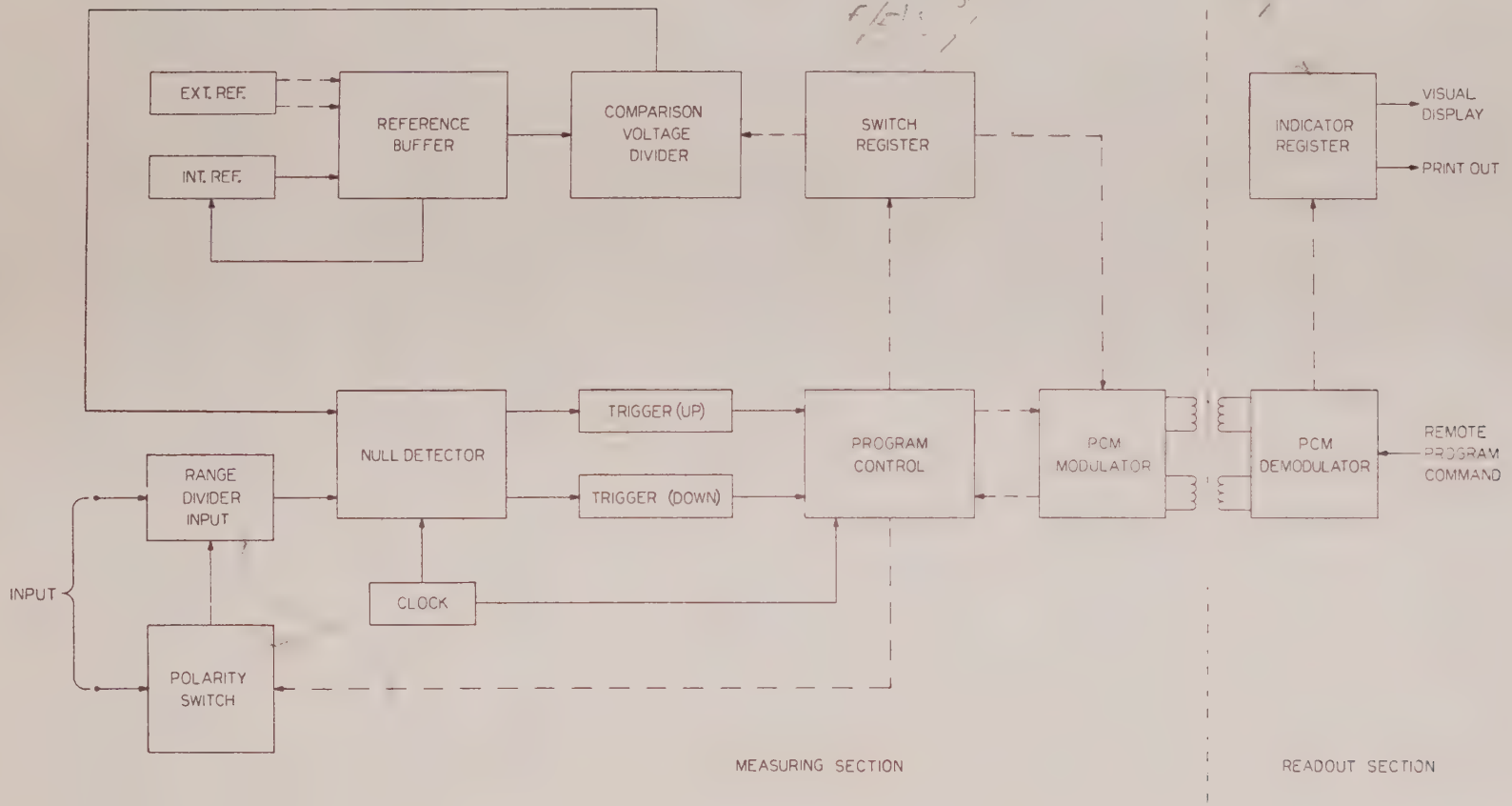


FIGURE 7.1 - Series 5000 Block Diagram

The purpose of the Null Detector is to compare, repetitively, the signal input with the Comparison Voltage. The sense of the difference is detected and amplified, and this information is used by the program control to change the N setting of the Comparison Voltage Divider. A logical sequence of changes, each change dictated by the comparisons that have preceded it, results in an N value that is within one part in 10,000 of the true input voltage. By using a system of Direct Digital Analysis (DDA), only 20 comparisons are required to reach this result. The comparisons are made at a rate of 300 per second in response to a 300 cps clock. Therefore, only 105 milliseconds are required for the complete measurement, not counting possible time-outs for range or polarity changes.

An outstanding feature of this DDA system is its fixed balancing time, making the Model 5000 ideally suited as a component of an externally programed data processing system. The instrument does not "search" for an answer, nor is the total elapsed time dependent on the value of the previous measurement. Instead, each time the "read" command is given, a totally new measurement is made through a Direct Digital Analysis of the input signal. Details of the DDA system are given in Section 7.6 which describes the Program Control.

The N setting in the Comparison Voltage Divider is determined by the state of flip-flops in the Switch Register, which in turn are set by signals from the Program Control. The setting of the Switch Register flip-flops is automatically and continuously reproduced in the Indicator Register, which is located in the output section. The information is telemetered from one Register to the other by Pulse Code Modulation. A Modulator-and-Demodulator is provided for this purpose. An identical return path is used to transmit remote program commands (read and range changes) to the Program Control.

The Indicator Register contains five decade banks, each controlling one of the Nixie Indicators. A sixth bank controls the polarity and decimal point. The information held by the Indicator Register can be transmitted to printout devices, using either ten-line decimal or binary-coded decimal signals.

When the instrument is operated in the "command" mode, the Switch and Indicator Registers hold the previous measurement until a subsequent "read" command is received. This may be in response to either push-button or remote commands, or to periodic commands generated by a 2. -cps clock that is part of the program control circuitry.

When the instrument is in a "tracking" mode, the Null Detector serves a second function. After the measurement has been completed, the Null Detector repeatedly compares the input signal with the N in the Comparison Voltage Divider. If the signal departs from the previous reading by more than a fixed threshold value, generally one digit, the instrument automatically takes a new reading. A manual control on the front panel allows the threshold to be set at any value from one to ten digits. Provision is also made for an automatic threshold control. In this case, the instrument is inhibited from taking a new measurement if the change in the signal is due to ac

28,000 RPM

noise. Only when the noise-plus-signal envelope has passed the threshold, does the instrument call for a new reading. In effect, the noise to signal ratio can become infinite without causing a read command.

7.2 COMPARISON VOLTAGE SUBASSEMBLIES

Three basic elements are used to generate a Comparison Voltage which, at null balance, exactly equals the input signal.

These elements are the Internal Voltage Reference, the Reference Buffer, and the Comparison Voltage Divider. The Internal Reference serves to stabilize the voltage output of the Reference Buffer, holding it constant within 100 ppm of a calibrated, 11.000 volt value traceable to the National Bureau of Standards Volt. This constant voltage, termed the Buffer Voltage, is divided down by a conductance network in the Comparison Voltage Divider to produce a Comparison Voltage that is a known fraction of the 11 volt Buffer Voltage.

Provision is also made for using an External Reference in place of the Internal Reference. Terminals are provided on the back of the instrument case for this purpose. A front-panel switch determines whether the instrument is to operate with an External or Internal Reference.

When an External Reference is used, the Reference Buffer amplifies the voltage by a factor of 1.1:1. Again, the resulting Buffer Voltage is stepped down by the Comparison Voltage Divider, exactly as in the case of the Internal Reference Mode, but now the digital value of the Comparison Voltage represents the ratio between the signal and the External Reference rather than providing an absolute voltage measurement.

7.2.1 Reference Buffer

The Reference Buffer is a high-gain direct coupled amplifier. The unit is completely solid-state, achieving extremely low voltage and current drift without the use of a conventional chopper stabilizing circuit.

The amplifier is a four-terminal device, allowing it to be used in either a potentiometric or an operational mode. In its role as the Reference Buffer, it operates as a negative feedback potentiometric amplifier.

7.2.2 External Reference

The function of the Reference Buffer amplifier is clarified by first considering its use with an External Reference. Figure 7.2 illustrates this arrangement. The ratio between the Buffer Voltage, V_O, and the Reference Voltage, V_i, is established by the value of resistances R1 and R2. This ratio is permanently calibrated at the factory at 1.1:1.

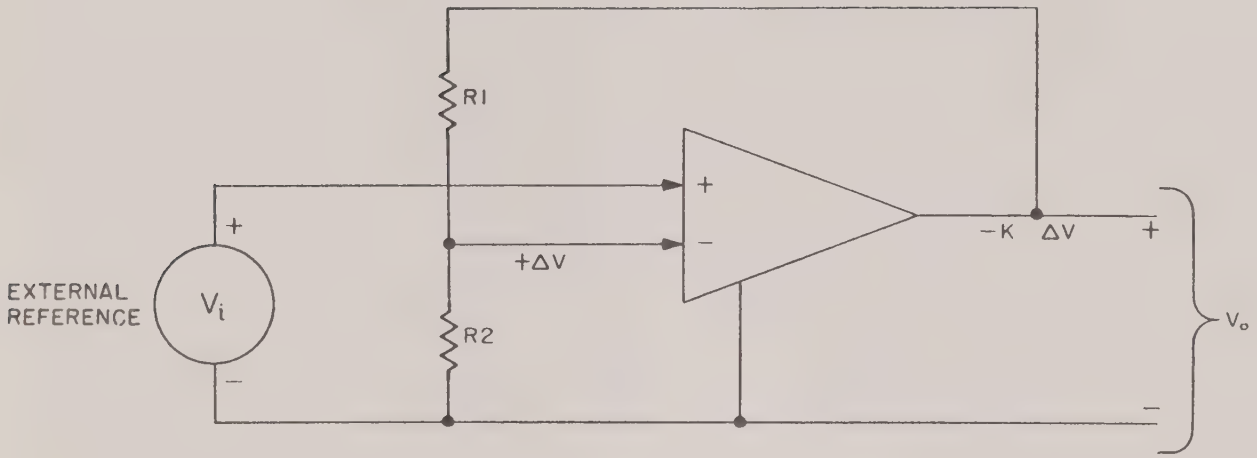


FIGURE 7.2 - External Reference and Buffer

The External Reference may be a battery or DC power supply with its positive terminal connected as shown. The External Reference input may be any voltage between 0 and slightly over 11 volts. The DVM's digital output will represent a ratio between the signal voltage and the reference used. If a Reference Voltage of exactly ten volts is supplied, the digital output may be read directly in volts. Reference voltages larger than 11 volts must be stepped down by resistance networks. A fuse is provided to protect the buffer amplifier from excessive reference voltages.

7.2.3 Internal Reference

Figure 7.3 shows the Reference Buffer connected to the Internal Reference circuit.

The Internal Reference is a divider network consisting of a fixed resistor, a potentiometer, and a Zener diode. The drive current for the Zener comes from the output of the Reference Buffer itself. Through careful selection of components and a balancing of the various resistances in the feedback network, an essentially zero temperature coefficient is achieved within the operating range of the instrument.

7.2.4 Comparison Voltage Divider

There are two basic forms of voltage divider suitable for a high accuracy potentiometer: series switch and shunt switch. The classic voltage dividers, (such as the Wolf-Poggendorf) are all of the series switch type. That is, the current through the divider flows through a substantial number of switch contacts in series. Series switching was a necessity because the only stable source of voltage was a battery, and batteries require a constant current load if they are to be used as a voltage reference.

The circuit designer today may choose between series switching or shunt switching, because the modern electronic buffer removes the necessity for a constant current load.

Shunt switching voltage dividers are simpler, use fewer components and eliminate the situation of a current flowing through large numbers of series contacts. For example, in a five decade, binary coded (Wolff) divider, the entire current must flow through twenty contacts. There are in addition, twenty contacts dangling from the voltage divider. These dangling contacts are very sensitive to leakage and electrostatic pickup. In the shunt switch voltage divider, every single contact is at a low impedance and free from the effects of leakage current or electrostatic pickup.

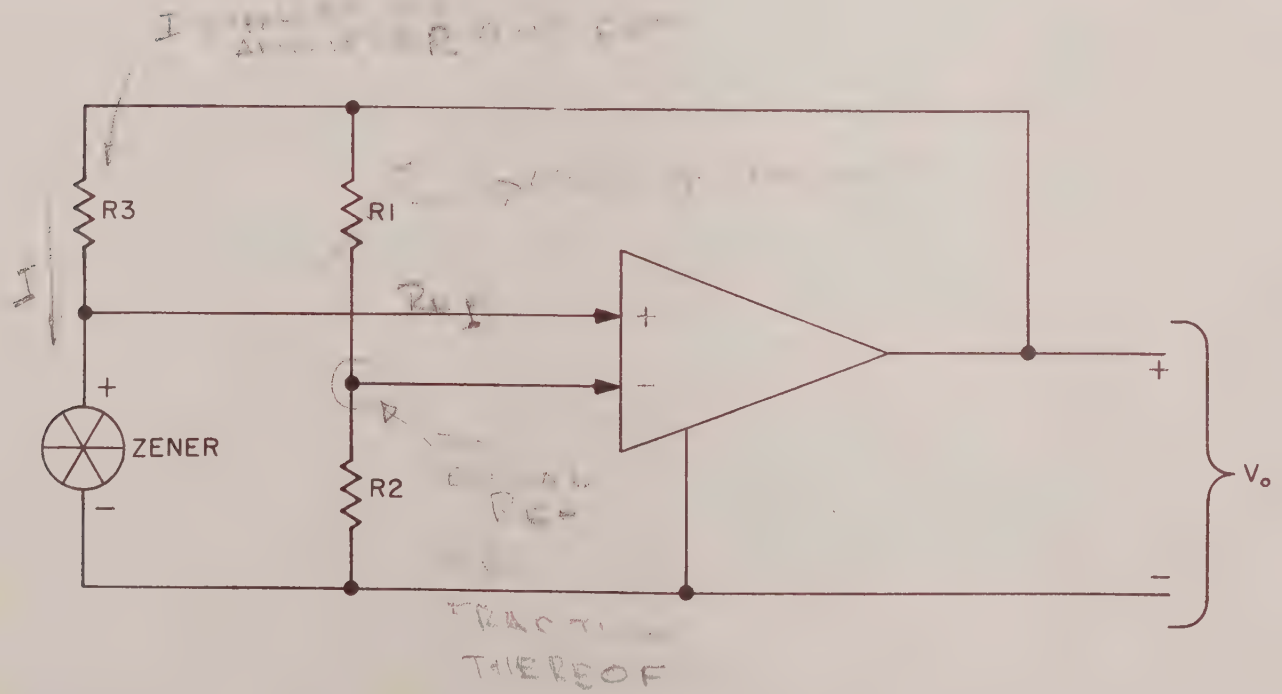


FIGURE 7.3 - Internal Reference And Buffer

Simplified series switch and shunt switch voltage dividers are compared in Figure 7.4.

Probably the greatest single advantage of the Shunt-Switch voltage divider is the ability to eliminate all moving parts. The switches can be transistors, rather than relays, stepping switches or other mechanical devices.

The transistor was recognized early in its development as a uniquely powerful switch: inexpensive, small, accurate, low driving power, reliable, and with virtually limitless life expectancy.

The principal departure from earlier switching components was the lack of a nominal isolation of the switch from the control. A transistor is turned "on" or saturated by a current through one of the switch tunnels and through the base, or third terminal. This control current precludes using transistors in a series switching voltage divider. There is no problem with this current, however, when shunt switching is used.

Each single-pole, double-throw switch requires a pair of transistor switches. This pair must be driven by complementary, or push-pull signals, one "on", the other "off". This is shown in Figure 7.5.

The basic principles of solid-state, shunt-switching are extended and highly refined in the Dana digital voltmeters.

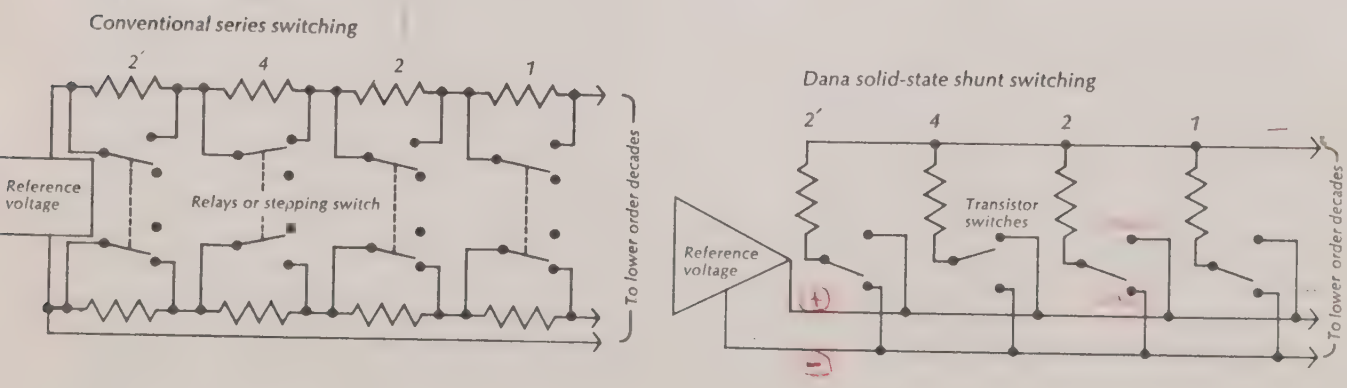


FIGURE 7.4 - Comparison of Series and Shunt Switching

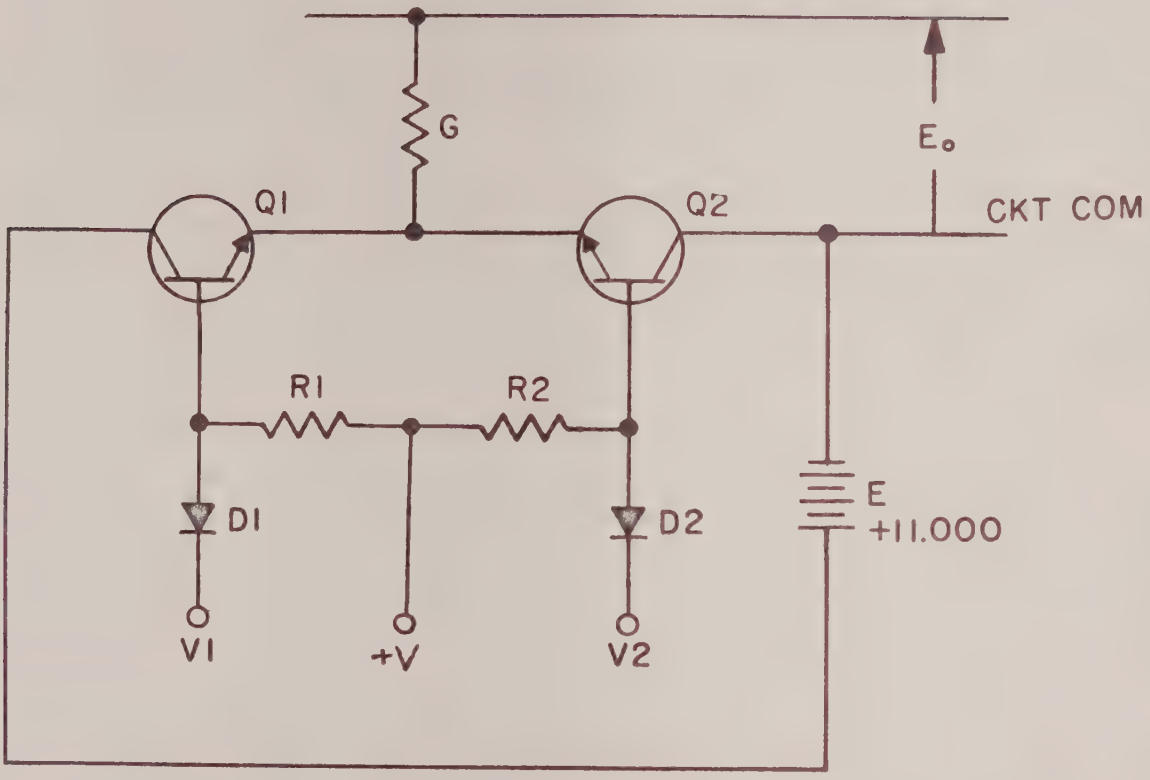


FIGURE 7.5 - Transistor Switch

The Comparison Voltage Divider is organized into five decades. Each decade is contained on a single etched circuit card. The circuits on the card include the switch register flip flops, the transistor switches and the resistors of that one decade.

These decade cards have no adjustments, nor trims of any type. Moreover, they are interchangeable between different Series 5000 instruments.

7.3 RANGE AND POLARITY SUBASSEMBLIES

The Dana Series 5000 DVM automatically adjusts for range and polarity.

If the input signal is larger than the Comparison Voltage, the input must be attenuated to a full-scale value than can be balanced. This is accomplished by the Input Range Divider. If the input lies between 10.000 and 99.999 volts, it is attenuated by a factor of 10. If it is between 100.00 and 999.99 volts, the signal is attenuated by a factor of 100.

Range selection is one of the sequence of steps performed by the Program Control each time a measurement is made. The logic employed in selecting the optimum range is described in the Program Control Section.

To produce a stable series of readings in the vicinity of the range-points, it is desirable to offset the up-range and down-range points. This offset is accomplished by up-ranging at the 9.9999- and 99.999-volts levels. Down-range changes are made at 09.909 and 099.09 volts.

Electro-mechanical relays are used in the Range Divider for two reasons. First, comparatively large voltages must be switched and no semiconductor elements of sufficient accuracy capable of handling such voltages are presently available. Second, range changes occur only once per measurement at most, and only if a comparatively large change in signal occurs; therefore, high-speed switching is not particularly required.

A polarity check is part of every measuring sequence. To achieve null-balance, the signal must be of the same polarity as the Comparison Voltage. The Polarity flip flop is activated by the Program Control, and connects the "volts common" lead to the proper side of the internal reference making a null-balance possible.

7.4 NULL DETECTOR (See Figure 7.6)

The function of the Null Detector is to determine which of two possible binary decisions should be taken as the result of each trial in the Direct Digital Analysis of the unknown signal. The Null Detector does not initiate any action, but enables the Program Control to make the appropriate decision at the start of the next clock cycle. Thus, the Null Detector needs to make only one determination per clock cycle.

The one-determination-per-clock cycle type operation is the heart of the high performance of the Dana Null Detector. The Null Detector is basically a very sensitive solid state electronic amplifier. This amplifier can resolve signals so small they are almost lost in the theoretical noise always present at room temperature. However, this performance is possible only for low impedances with available semiconductor devices.

In the Series 5000, this sensitivity is combined with very high impedance by an exchange of time-for-impedance. The off-null signal is accumulated for a relatively long time, then used in a very short time. The accumulation is upon a capacitor which is switched to the input of the Null Detector amplifier once per clock cycle.

The accumulated charge is converted into a high signal-to-noise ratio voltage pulse which is greatly amplified. The actual pulse amplifier is resolved into two cascaded negative feedback amplifiers in cascade, and an inverter to produce a push-pull output. Over a span equivalent to a few digits change of the comparison voltage, the negative feedback maintains a high gain accuracy independent of component variations, temperature and other extraneous effects. Large signals are severely limited, and actually overload the amplifiers, but the amplifiers completely recover to respond to the smallest signal which may follow.

A solid-state attenuator, normally operated at one fixed level, connects the two negative feedback amplifiers. Only in the manual threshold tracking mode is this level altered. During the time between measurements, this level is switched to the level selected by the Manual Threshold control. Reducing the gain increases the threshold of input voltage change needed to command a new measurement.

Each of the two push-pull outputs drives a separate bistable trigger. Both triggers are reset prior to the pulse. The first trigger to receive a greater than threshold positive pulse is set and remains set until the information is to be used. This is discussed in greater detail in Section 7.5.

7.4.1 Comparison Chopper

The means for switching a long time-high impedance signal to the amplifier is a Bristol Synchrovertor. The Synchrovertor is driven continuously in synchronism with the digital clock signal, which is 300 cycles per second. During approximately one half of each cycle, the transfer capacitor is charged to the input voltage level, then at the start of the other half cycle, the transfer charge is used.

7.4.2 Transfer Capacitors

The charge is stored by a high quality silver mica capacitor. The magnitude of the storage capacitor is a compromise between noise level and off-null input resistance.

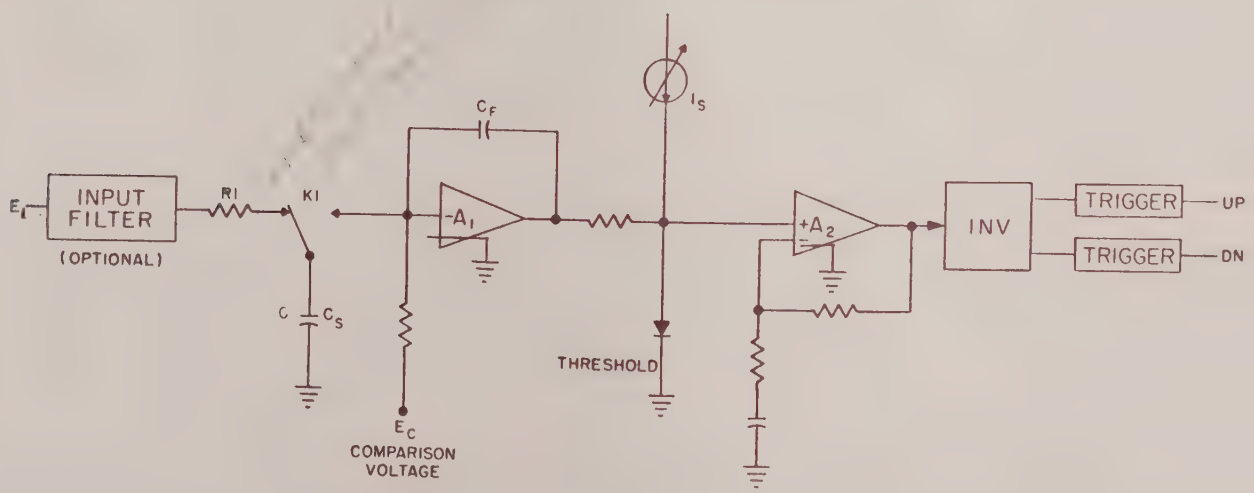


FIGURE 7.6 - Null Detector Subassemblies

7.4.3 Kick Back Charge

The off-null resistance of the Dana Null Detector is infinite in the usual sense. There is, however, an effect of reverse transfer or kick back of charge from the comparison voltage to the signal source. This kickback is present in all potentiometers and is one of the fundamental parameters which describe a potentiometer. This charge cannot be zero for theoretical reasons, but should be as small as possible.

In the Dana Null Detector, the kickback charge per comparison is very near the theoretical limit established by the selected noise level. For example, at 100 microvolts per digit, the transfer capacitor is only 230 picofarads. The theoretical noise voltage associated with a capacitor of this size is 5 microvolts rms, or peak of about 30 microvolts. The Dana Null Detector actually operates within a factor of about two of the theoretical limit.

The kickback charge per measurement is further reduced by the direct digital analysis logic of the Series 5000. This logic minimizes the number of comparisons required to make a measurement.

7.4.4 Off-Null Resistance

Variations in time per comparison and in the number of comparisons per measurement limit the meaning of off-null input resistances. Nevertheless, this parameter is significant. Resistance in the usual sense is infinite in the Dana Null Detector, however, kickback charge per volt of error per unit time has the dimension of conductance, or 1/R. In this sense, the off-null input resistance is (1/FC) where F is the frequency of comparison and C is the transfer capacitance. At 300 comparisons per second, the equivalent resistance is 10 megohms at 100 microvolts per digit.

7.4.5 At-Null Resistance

The maximum residual difference between the input and comparison voltages is one half digit plus peak noise, or considerably less than one digit. The apparent, or at-null resistance due to the Null Detector will exceed 10,000 X off-null resistance or 10^{12} ohms. This is not fully realized since the Null Detector is shunted by input cable leakages, range relays, etc. The 1000 megohm (10^9) specifications is a conservative value.

7.4.6 Signal Source Resistance

The at-null resistance of an exactly balanced potentiometer, without shunt leakages, is infinite. This is somewhat misleading in that it conveys the untrue notion that extremely large signal source resistances can be handles without error. The measurement cannot exceed the accuracy of the individual comparisons. Therefore, the signal source resistance is limited to less than the off-null resistance for full accuracy. This is characteristic of all potentiometers.

If the signal source resistance is not small relative to the off-null resistance of the Null Detector, there is an inherent loss of accuracy, although measurement is possible. In many manually balanced potentiometers, the Null Detector has a resistance of only 25 ohms, a minute fraction of the 10 megohms of the

7.4.7 Null Detector Preamplifier

The first of the Null Detector amplifiers is the Null Detector Preamplifier. This amplifier produces a pulse peak equal to five millivolts per digit error in the Comparison Voltage, for small errors. Although only pulse-type signals are to be amplified, this amplifier is direct coupled to assure stable, accurate amplification.

7.4.8 Manual Threshold Control

The Manual Threshold control is a solid-state gain attenuator consisting of one fixed resistor and a forward biased diode. The dynamic resistance dV/dI of this diode is controlled by a DC current. The greater this DC current, the lower the diode's dynamic resistance and the larger the threshold. This DC current is held at zero, except between measurements in the Manual Threshold mode.

7.4.9 Trigger Drive Amplifier

The output from the Manual Threshold control attenuator is further amplified by the Trigger Drive Amplifier. This is a simple two-stage amplifier with potentiometric feedback for gain stability and to minimize loading upon the attenuator. The amplifier is direct coupled, with operating point feedback to assure independence from component variations or changes with aging or temperature.

7.4.10 Inverter

The Inverter provides two outputs identical in amplitude, form and impedance level, but of opposite sense. If the pulse is positive, one output from the Inverter will be a positive pulse; if the off-null pulse is negative, the opposite output will be a positive pulse. The Inverter also provides a limited voltage gain heavily stabilized by degeneration.

7.4.11 Bistable Triggers

The logic circuits in the Program Control section function from two steady-state voltage levels and clock edges. The pulses representing off-null must be converted into these steady state voltage levels. Two bistable triggers are used. These are identical, but driven by opposite sense pulses from the Inverter. In anticipation of each pulse, both triggers are reset: the first trigger to be set by a negative pulse in excess of threshold remains set until the next comparison and

forbids the opposing trigger from being set.

In this way, each pulse is converted into two binary signals. These are translated into two dependent binary functions. Up or $\overline{\text{Up}}$ (not Up), and Down or $\overline{\text{Down}}$ (not Down). There are three possible qualitized and stored outputs:

$$\text{Up} - \overline{\text{Down}}$$
$$\overline{\text{Up}} - \overline{\text{Down}}$$
$$\overline{\text{Up}} - \text{Down}$$

The condition $\overline{\text{Up}} - \overline{\text{Down}}$ is a null. This is used only in the tracking mode to indicate that no new measurement is indicated. Either an Up - $\overline{\text{Down}}$ or an $\overline{\text{Up}}$ - Down will command a new sample.

During the actual measurement sequence, the binary choice between Down and $\overline{\text{Down}}$ is used only to test and correct the polarity. All other actions are based upon a simple binary choice Up or $\overline{\text{Up}}$. Either choice produces a definite action, never an indecision or no-action state.

7.5 CLOCK

The digital portions of the Dana DVM are identical in principal to an electronic digital computer. There are only a few types of circuits and a few types of operations, although the combination may appear to be complex.

One of the basic circuits is called a flip flop. There are three inputs to each flip flop, two DC voltage levels and a clock. Each flip flop remains in one of two states, set or reset until the opposite input has been true for some time, then action is taken by a clock edge. Without the clock edge, no action is taken.

The flip flops and associated gates are very fast, reaching a new final value within a few microseconds after each clock edge. Except for these few microseconds, the logic of the DVM is independent of time and wholly dependent upon the clock edges.

Since the flip flops use NPN type transistors, the clock edge is an abrupt change in voltage level from a positive voltage or true, to power supply common or false.

The logic will operate at rates up to tens of thousands of edges per second. A lower clock rate is dictated by other requirements, notably the low power level of microvolt signals from megohm sources.

In the Series 5000, the clock rate is 300 cycles per second. The clock is a free running multivibrator which runs continuously whether a measurement is being made or not. This clock signal is generated wholly within the DVM and does not rely upon AC line frequency or other external signals.

The basic oscillator operates at 2 x the clock frequency and a binary counter divides the frequency, producing a symmetrical square wave to drive the synchrovertor. Since the synchrovertor is driven continuously, it is a simple matter to phase the critical contact to precede the clock edge.

7.6 PROGRAM CONTROL

The Program Control Subassemblies include the logic matrix required for the Direct Digital Analysis, plus the Switch Register which determines the value of the conductances in the Comparison-Voltage Divider.

The Program is controlled principally by a four-bit Program Counter capable of counting up to 16 Program Steps. These are numbered 0 through 15.

Program Steps 0 through 14 provide the measurement cycle. Program Step 15 is a standby position in which the Program Counter remains stationary until a new read command is given. Once the Counter has been switched to Program Step 0, it proceeds through to Program Step 14 without halt.

Program Step 0 verifies polarity by jamming N to zero. An Up - $\overline{\text{Down}}$ combination of signals from the two triggers verifies polarity and the Program proceeds on the next clock cycle to Program Step 1. An $\overline{\text{Up}}$ - Down signal changes the state of the polarity flip flops and sets a time-out of approximately ten milliseconds to permit the polarity relay to follow. No further action occurs until the time-out is completed.

Program Step 1 checks to see if up-ranging is required. The Program Control jams N to full scale or 99,999. If an $\overline{\text{Up}}$ signal is received, the instrument proceeds to Program Step 2. However, if an Up signal results, the signal is off scale and the Range Counter is jammed to the least sensitive range, the highest range.

The Range Counter is a two-bit binary counter with four possible ranges. Code 00 is the least sensitive range. The 100 volt range is 01, the 10 volt range is 10. Accessory function can add additional ranges.

It is theoretically possible to evaluate range directly in three program steps. However, the range relays are necessarily slow and have relatively limited life expectancies. To minimize measurement time and avoid unnecessary relay operations, range is presumed to be correct and is changed only if necessary. Program Step 1 senses, in effect, if an up-range is imperative.

Program Step 2 checks to see if down-ranging is required. The number N is jammed to the down-range threshold value (09909). If an Up signal results, Best Range is verified. If an $\overline{\text{Up}}$ signal results, a more sensitive range is needed. The Range Counter is advanced to the next more sensitive range and a time-out of ten milliseconds is allowed for the relay to follow.

Program Step 2 is then repeated until the Best Range is verified, or the most sensitive allowed range is reached. When the Best Range has been verified, the program counter advances to Program Step 3.

Program Step 3 is the start of the Direct Digital Analysis sequence, which in 20 trials will arrive at a digital representation of the input signal. Step 3 sets all of the bits in the Switch Register to nine.

Program Steps 4, 5, 6, and 7 are used for the Direct Digital Analysis of one decade. Figure 7.7 illustrates the procedure. Each of the conductance values in the decade is dropped in succession. If an Up signal is received, the dropped value is replaced. If an $\overline{\text{Up}}$ signal is received, the conductance is not replaced. Only four trials are required to obtain a number from 0 to 9 that exactly equals the digital value of the input signal for that decade. (See Figure 7.7)

Program Steps 4 through 7 are repeated five times, once for each decade.

When the final decision has been made (for the 1 bit in the least significant decade), the Program Counter proceeds to Program Step 8.

Program Step 8 is used during the Tracking Mode to add a half-digit of conductance to the setting the Voltage Divider. The effect is to move the Comparison Voltage to the mid-point of the one-digit range signified by the least significant digit. This value is compared to the input signal during the monitoring period, and a new reading is commanded if the departure exceeds one full digit.

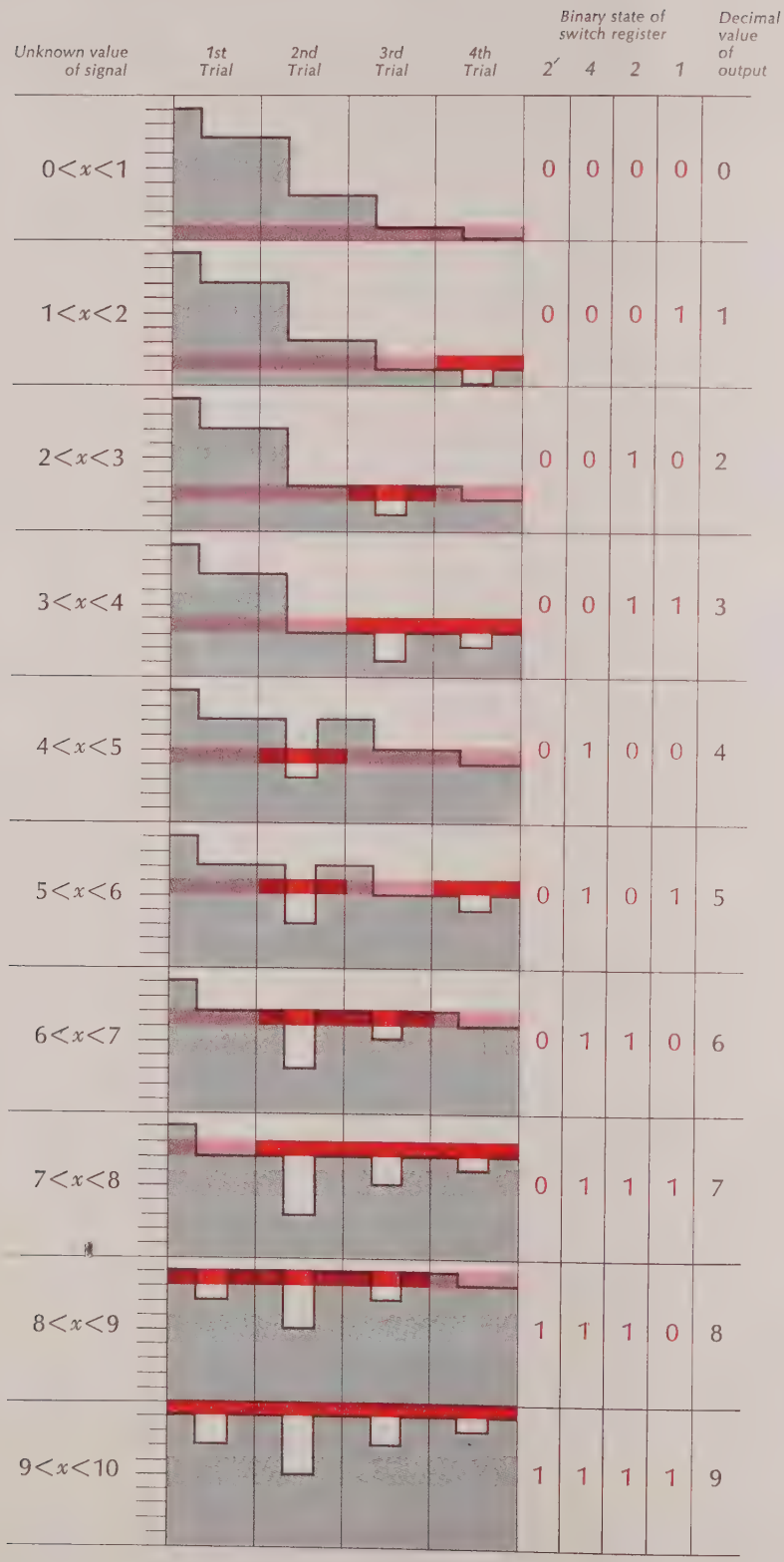
Following this decision, the Program Control proceeds through Steps 9, 10, 11, 12, 13, and 14 where the counter stops until ordered to proceed to the stand-by position, Step 15.

Program Steps 9 through 13 are used for the electrical readout (see Section 7.7.2).

7.6.1 Tracking Mode

In the Tracking Mode, the instrument monitors the input signal and calls for a new reading whenever the signal change exceeds a threshold value.

The decision whether to make a new reading is made during each clock cycle, or 300 times a second. If no change has occurred, the input signal will continue to match the Comparison Voltage, and the Program Control will receive an $\overline{\text{Up}}$ - $\overline{\text{Down}}$ signal from the Null Detector. When the signal changes beyond the threshold value, the Null Detector will transmit either an $\overline{\text{Up}}$ - Down or an Up - $\overline{\text{Down}}$ signal. This will cause the Program Control to move from Program Step 15 to Program Step 0, which in turn initiates the measurement cycle. At the end of the measurement, the Program Counter stops at Step 15 until a new indication of signal change has been received.


Unknown value of signal
1st Trial
2nd Trial
3rd Trial
4th Trial
Binary state of switch register
2′ 4 2 1
Decimal value of output
0<x<1 0 0 0 0 0
1<x<2 0 0 0 1 1
2<x<3 0 0 1 0 2
3<x<4 0 0 1 1 3
4<x<5 0 1 0 0 4
5<x<6 0 1 0 1 5
6<x<7 0 1 1 0 6
7<x<8 0 1 1 1 7
8<x<9 1 1 1 0 8
9<x<10 1 1 1 1 9

The chart to the left illustrates the simplicity of the Direct Digital Analysis technique used to determine the decimal value of the unknown signal for a single decade. Each of the four trials results in a binary decision, stored in the voltage divider switch register, and the sum of these decisions determines the decimal value of the output.

The input signal can have ten possible values as illustrated by the ten green bands across the chart. The comparison voltage is shown in gray. The only decision made during each trial is whether the comparison voltage is larger or smaller than the unknown value of the signal.

The initial value of the comparison voltage is set at 9 by switching in all four resistors (representing respectively 2′, 4, 2, and 1) in the voltage divider. The 1st Trial consists of dropping the 2′ resistor. If the resulting comparison voltage is smaller than the signal, the resistor is replaced and the switch register records a binary ONE. If the comparison voltage is larger than the signal, the resistor remains out, producing a binary ZERO. This process is repeated with the 4, 2 and 1 resistors. At the end of four trials, the switch register contains a binary coded decimal value that is an exact digital representation of the unknown signal. The 2′421 code is translated into standard 8421 code which is telemetered to the output section by a PCM link.

FIGURE 7.7 - Direct Digital Analysis

The normal threshold value is one digit. Noise on the signal in excess of one digit will call for repeated measurements, and these are likely to recur so swiftly that the eye cannot detect the individual values displayed. Two techniques are provided for limiting this effect. One is a manual increase in the threshold value, accomplished by the method described in Section 7.4.8 above.

The other technique is to inhibit the taking of a new measurement whenever there is AC noise on the signal and the previous reading continues to lie within the signal-plus-noise envelope. The inhibiting circuit monitors the Null Detector signals, continuously evaluating whether both Up - $\overline{\text{Down}}$ and $\overline{\text{Up}}$ - Down signals have been received during a preset period of time. If so, AC noise is presumed to be on the signal; therefore, no new measurement is permitted. As soon as the noise-plus-signal envelope has departed from the previous reading by two digits, correction signals of only one sense will be received during the observation period and a new reading is ordered.

This "automatic threshold" technique does not reduce the accuracy of the instrument nor its tracking ability, since it introduces no errors that are not already present due to the noise on the signal. In effect, it automatically compensates for an infinite amount of noise, preventing the instrument from making measurements that have no more validity than the stored reading.

7.6.2 Command Mode

In the Command Reading Mode, the instrument retains its last reading on the visual display until a new reading is ordered. The read "command" moves the Program Counter from Step 14 through Step 15 to Step 0. This double progression ensures that no spurious signal will erase the previous value by starting the instrument on a new reading cycle.

Single-cycle commands may be initiated by either a push button on the front panel or by a contact closure or pulse on the remote command cable (see Section 7.7.5). In this mode, the reading remains stationary for an indefinite period of time. The only way that the reading will change is if a second command is given, or if the manual range control is shifted.

The "Periodic" mode is also a command mode, except that in this case, the commands are generated by an internal timing circuit.

7.6.3 Switch Register

The resistors in the Comparison Voltage Divider are controlled by flip flops in the Switch Register. One of the features of shunt switching is that only one switch is required per bit; therefore, the state of the flip flops in the Switch Register is a digital representation, in 2'421 code, of the Comparison Voltage.

7.7 READOUT SUBASSEMBLIES

To maintain isolation of the sensitive measuring circuits, even when the instrument is tied to a remote readout or programming device, the readout subassemblies are contained in a separate, isolated compartment within the instrument. Digital information is transmitted from one compartment to the other by a transformer-coupled PCM link. Remote commands enter the measuring section by an identical return path.

7.7.1 Pulse Code Modulation

The principal purpose of the PCM link is to telemeter the state of the flip flops in the Switch Register so that the same digital values may be reproduced in the Indicator Register (see below) in the Readout Section.

Approximately one-quarter of an inch separates the two compartments. The PCM link includes two sets of modulators and demodulators, plus transmitting and receiving heads on the interface walls.

The outgoing PCM path carries digital information, polarity, range and an end-of-reading signal. The incoming path carries remote range and read commands. For convenience, the 2'421 code of the Switch Register is translated to 8 4 2 1 weighting for transmission by the PCM link.

7.7.2 Indicator Register

The Indicator Register is a serial shift register that, in effect, duplicates the state of the flip flops in the Switch Register, but in the 8 4 2 1 code.

Program Steps 9, 10, 11, and 12 are provided to allow the PCM link to transmit to the Indicator Register the state of the polarity and range flip flops. Program Step 13 transmits an end-of-sample signal that locks the information in the Indicator Register and makes it available for immediate use.

7.7.3 Nixie Display

The Nixie Display is activated by the Indicator Register. A separate circuit card is provided for the drive and control circuits for each Nixie bulb.

7.7.4 Remote Printout

Printout signals are available in either parallel decimal or binary-coded-decimal form.

7.7.5 Remote Program

Remote read commands are ordered by voltage-level changes on leads entering the instrument through the connector used for remote readout. (Certain instruments are also wired for remote range commands.)

8. SERVICE AND MAINTENANCE

The Dana DVM has been designed and manufactured to operate for years with no repair, maintenance, or service, other than periodic recalibration. The probability of malfunction has been made very small, but this probability cannot be made zero. Therefore, the instruments have also been made unusually simple to restore to full operation. Field repair can be performed by personnel with limited skill and knowledge within minutes, without even removing the DVM from the rack, nor disconnecting it from associated equipment.

The basic technique of field service is substitutional checking. In substitutional checking, a subassembly which is known to be operative is substituted for a subassembly which is suspected of malfunctioning. If the malfunction is isolated, and the one malfunctioning subassembly replaced, service is restored.

Substitute checking is extremely easy. The subassemblies are all similar, etched circuit cards approximately 4 1/2" x 10 1/2". These cards are all accessible through the opening at the front of the instrument, with the instrument mounted in a relay rack. Virtually every electronic component is mounted on these cards.

These subassembly cards are the basic spare parts. A full set should be available for field service, since these are not merely spare parts, but also the most powerful single trouble-shooting tool possible.

The chart which follows will serve as a guide as to the probable source of trouble.

8.1 TROUBLE SHOOTING CHART

Fault	Corrective Action
No change of reading on command No apparent range change No apparent polarity change No overrange indication	Replace Card in Location 01
No 100's digit indication No 100's digit change Double number on 100's digit	Replace Card in Location 04
No 10's digit indication No 10's digit change Double number on 10's digit	Replace Card in Location 05

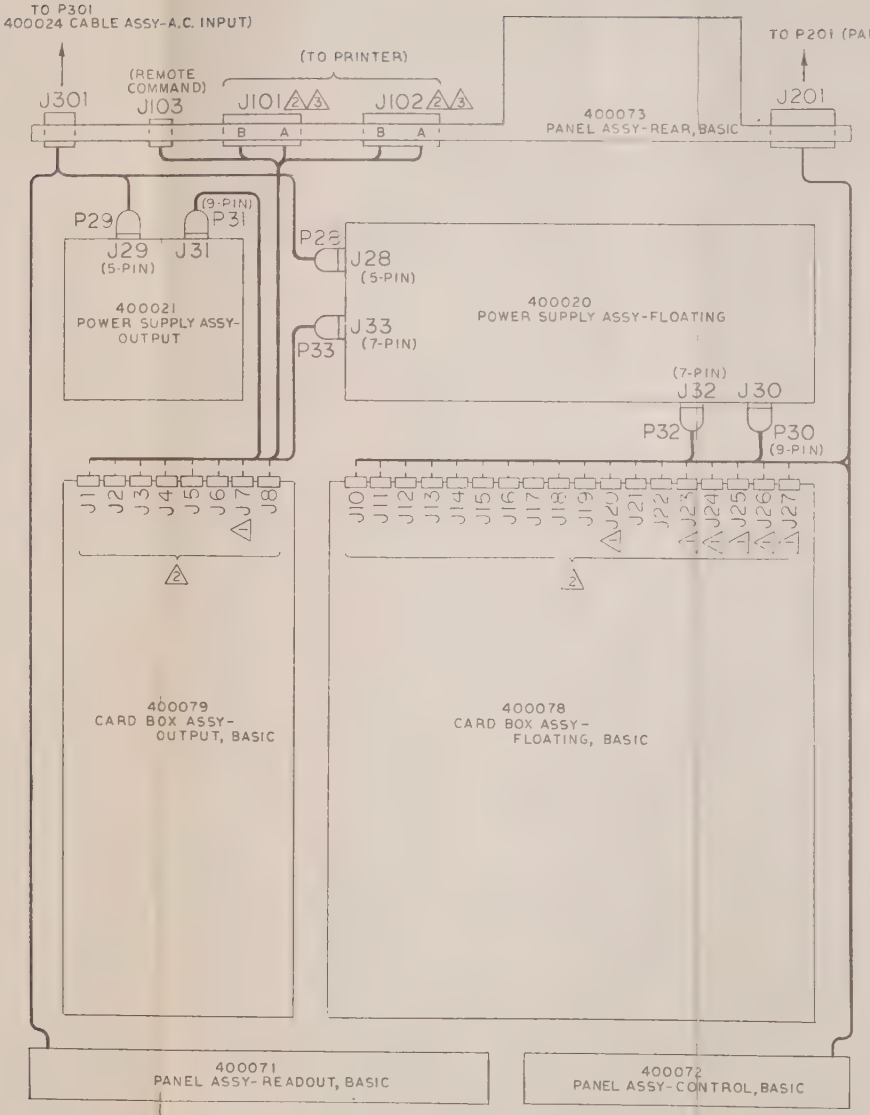
Fault	Corrective Action
No 10,000's digit indication No 10,000's digit change Double number on 10,000's digit	Replace Card in Location 02
No 1000's digit indication No 1000's digit change Double number on 1000's digit	Replace Card in Location 03
No units indication No units change Double number on units digit	Replace Card in Location 06
No change of reading on command Fails to printout Fails to respond to remote command	Replace Card in Location 08
No change of reading on command Fails to respond to remote command	Replace Card in Location 10
Fails to range automatically Fails to respond to manual range change Range relays operate continuously, but readout does not change No change of reading on command	Replace Card in Location 11
No change of reading on command Fails to make polarity change Fails to make range change Following a range or polarity change on manual command, produces one or two erroneous readings	Replace Card in Location 12
No change of reading on command Avoids certain numbers in units digit	Replace Card in Location 15
No change of reading on command Avoids certain numbers in 10's digit	Replace Card in Location 16
No change of reading on command Avoids certain numbers in 100's digit	Replace Card in Location 17
No change of reading on command Avoids certain numbers in 1000's digit	Replace Card in Location 18
No change of reading on command Avoids certain numbers in 10,000's digit	Replace Card in Location 19

Fault	Corrective Action
No change of reading on command, plus no audible chopper noise Periodic reading mode does not operate, but all others do Periodic readings flash, but fail to change with signal Automatic threshold mode is not operative	Replace Card in Location 13
Erratic readings from known stable source One reading mode operates, but others do not Fails to make polarity change Fails to respond to fixed range changes	Replace Card in Location 14
Responds to command, but there is no audible chopper noise Fails to make polarity changes Fails to make range changes Cycles on command, but reading does not change Offset zero point	Replace Card in Location 21
Readings out of calibration Unable to take stable readings Meter reads all zeros or all nines continuously	Replace Card in Location 22
Erratic readings Unnecessary range or polarity changes Unstable readings on manual threshold	Replace chopper on Card in Location 21
Nixie does not light Individual numbers do not light	Check or replace Flexprint cable
Display fails to light when power is turned on	Replace fuse
Nixie fails to light Fails to respond to command	*Use extender card to check Indicator Register power supplies Locations 01-08:

Terminal	Voltage
M	$-20 \pm 20\%$
N	$+ 6.8 \pm 10\%$
P	$+ 18 \pm 20\%$
R	Common

Fault	Corrective Action
Fails to operate on "Ratio x 10"	Replace fuse on Card in Location 22

*A Dana DVM Extender Card assembly may be ordered under part #400035. It includes the basic extender card, a support bracket and all required coaxial extension cables to service the basic DVM or any of the optional accessories.



4. J9 REF DESIGNATION NOT USED.
3. CONNECTORS J101-A &B & J102-A&B IN SOME CASES (B.C.D.) WILL NOT BE USED. IN THESE UNITS J101-B IS REPLACED BY J101.
2. CONNECTORS INDICATED ARE NOT PART OF BASIC SUBASSY.

NOTES: 1. CONNECTORS INDICATED ARE NOT USED ON STANDARD DVM.

FIGURE 8.1 - Interconnection Diagram

JAN
RANGE

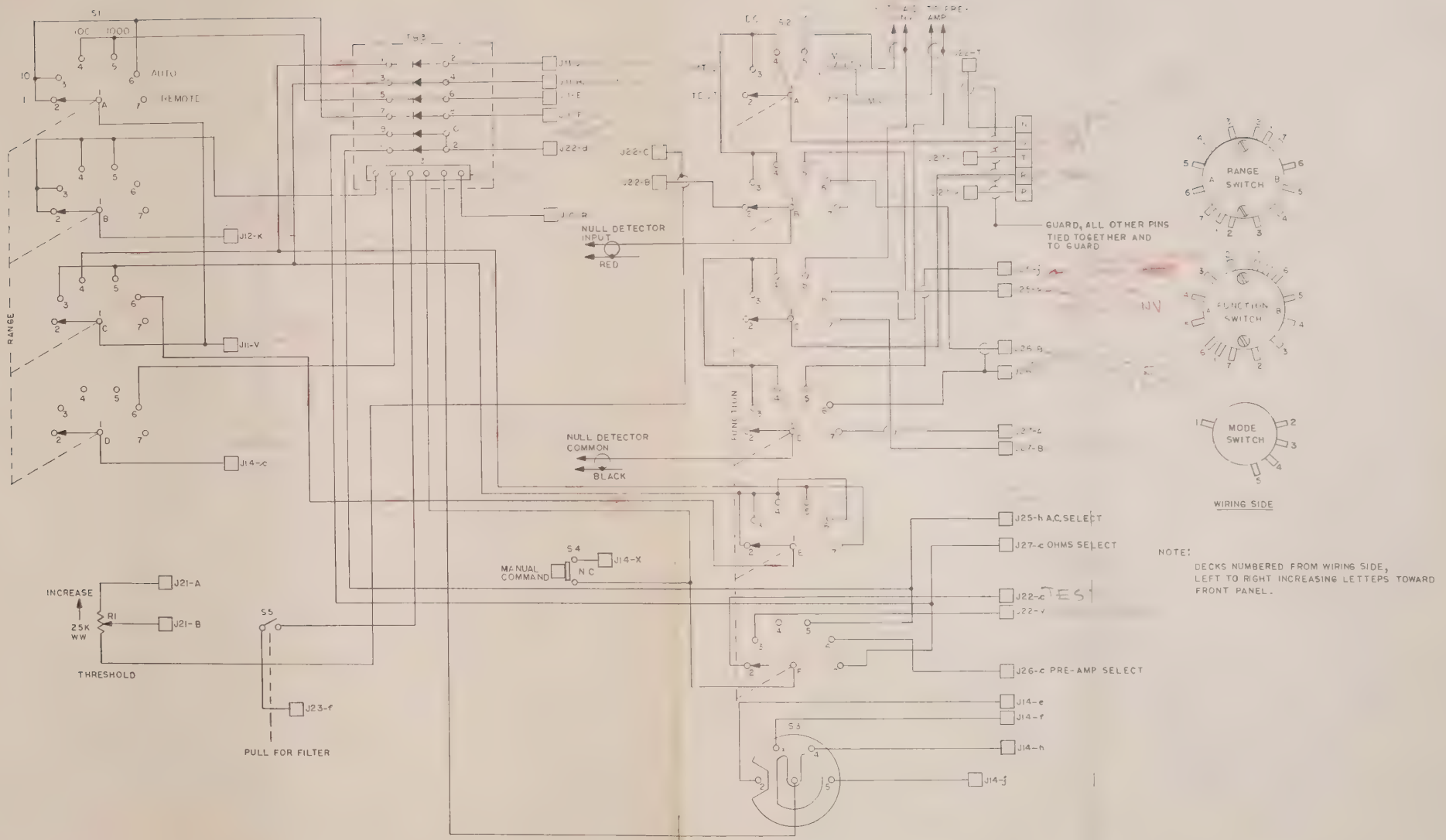
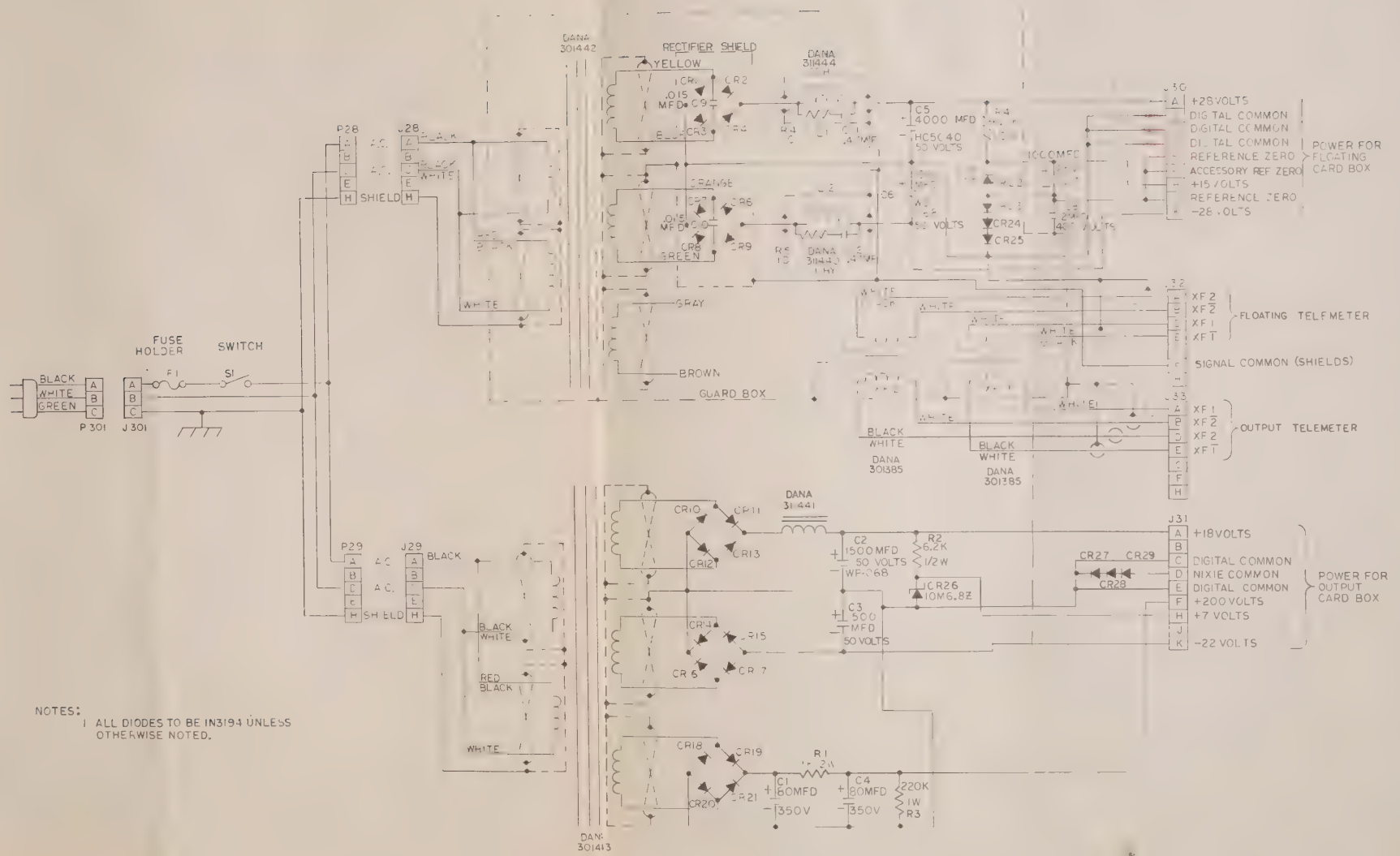
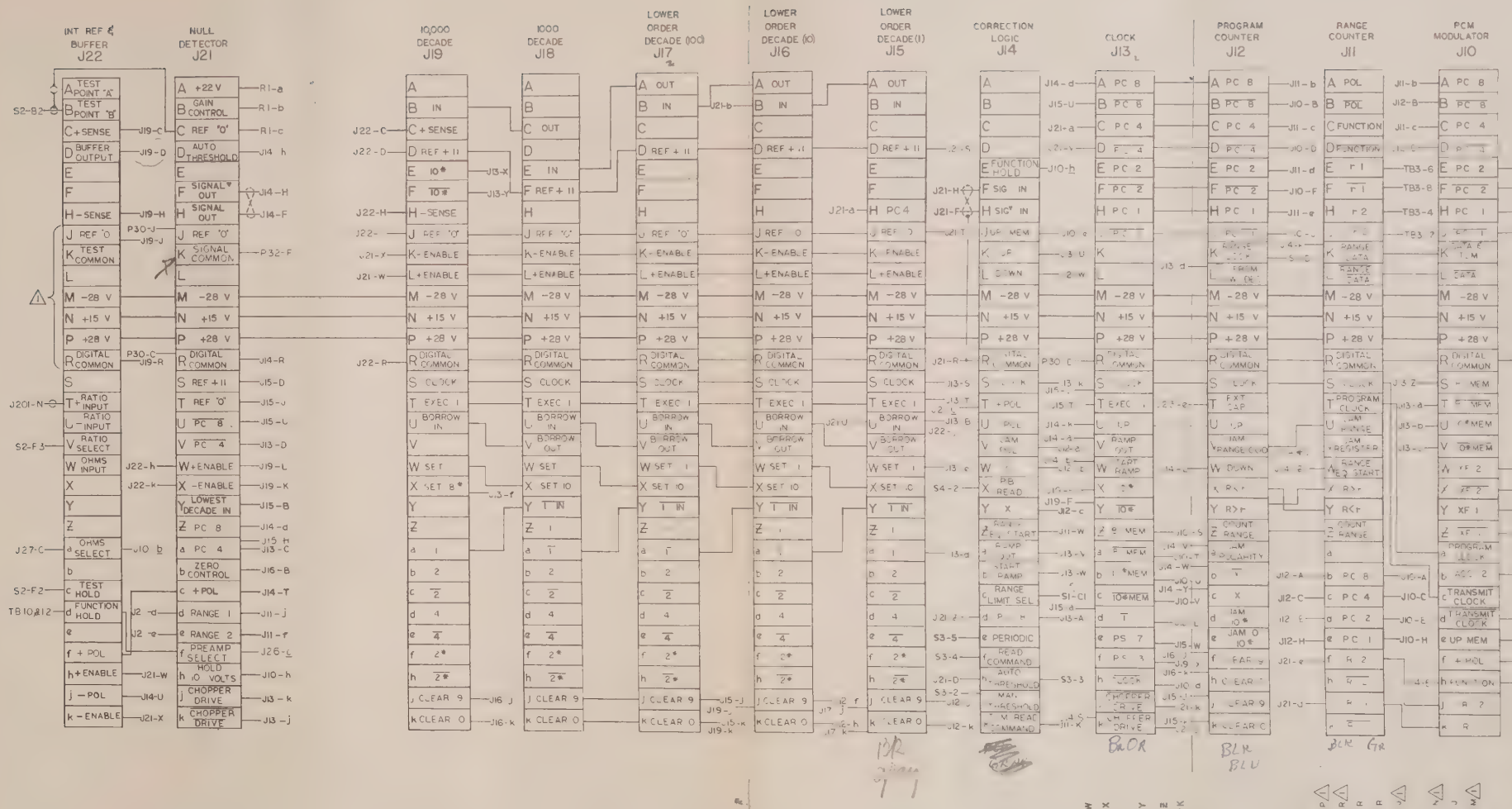


FIGURE 8.2 - Wiring Diagram
Control Panel



NOTES:
1. ALL DIODES TO BE IN3194 UNLESS OTHERWISE NOTED.

FIGURE 8.3 - Schematic Diagram
Power Supply Assembly

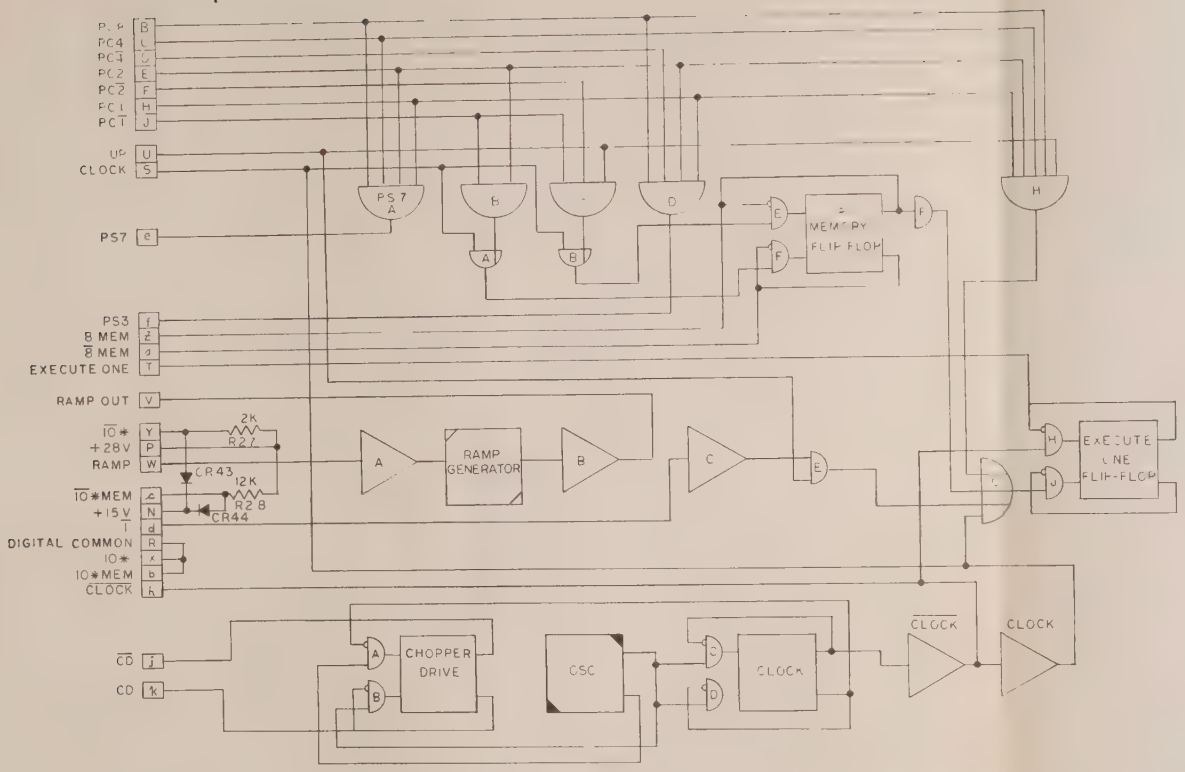


Notes: Late model instruments are prewired for all accessories unless programming option is supplied.

This wiring diagram contains all floating card box wiring common to all 5-digit voltmeters; accessory connector wiring (if the unit has specified accessories) is to be added per the pertinent wiring diagrams.

If the unit is equipped with accessory connectors (J27, J26, J25, J24, J23), P30 terminals A, B, E, H, & K will be wired to pins P, R, J, N, & M respectively of the first accessory connector encountered in the list above rather than to J22.

FIGURE 8.4 - Wiring Diagram
Floating Card Box



NOTES: UNLESS OTHERWISE SPECIFIED.
1. ALL RESISTORS 1/4 WATT ±5%.
2. ALL DIODES IN662.
3. ALL TRANSISTORS 2N1304.

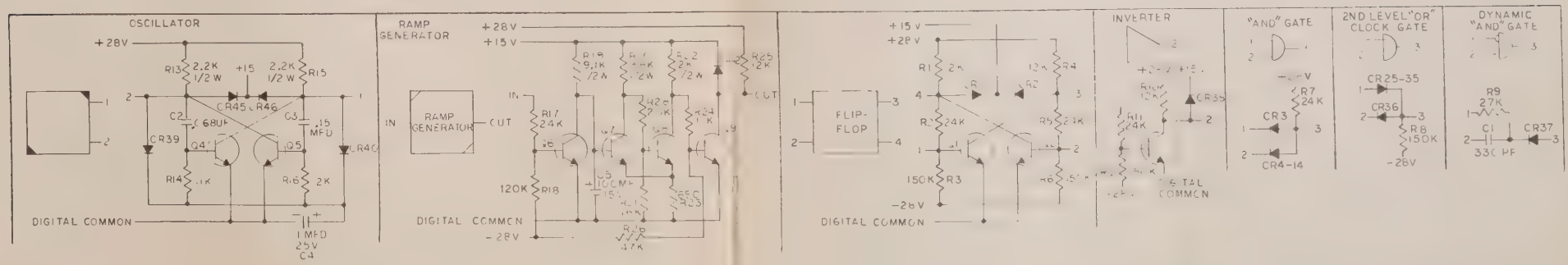


FIGURE 8.5 - Schematic Diagram
Clock Card
(Brown-Orange)

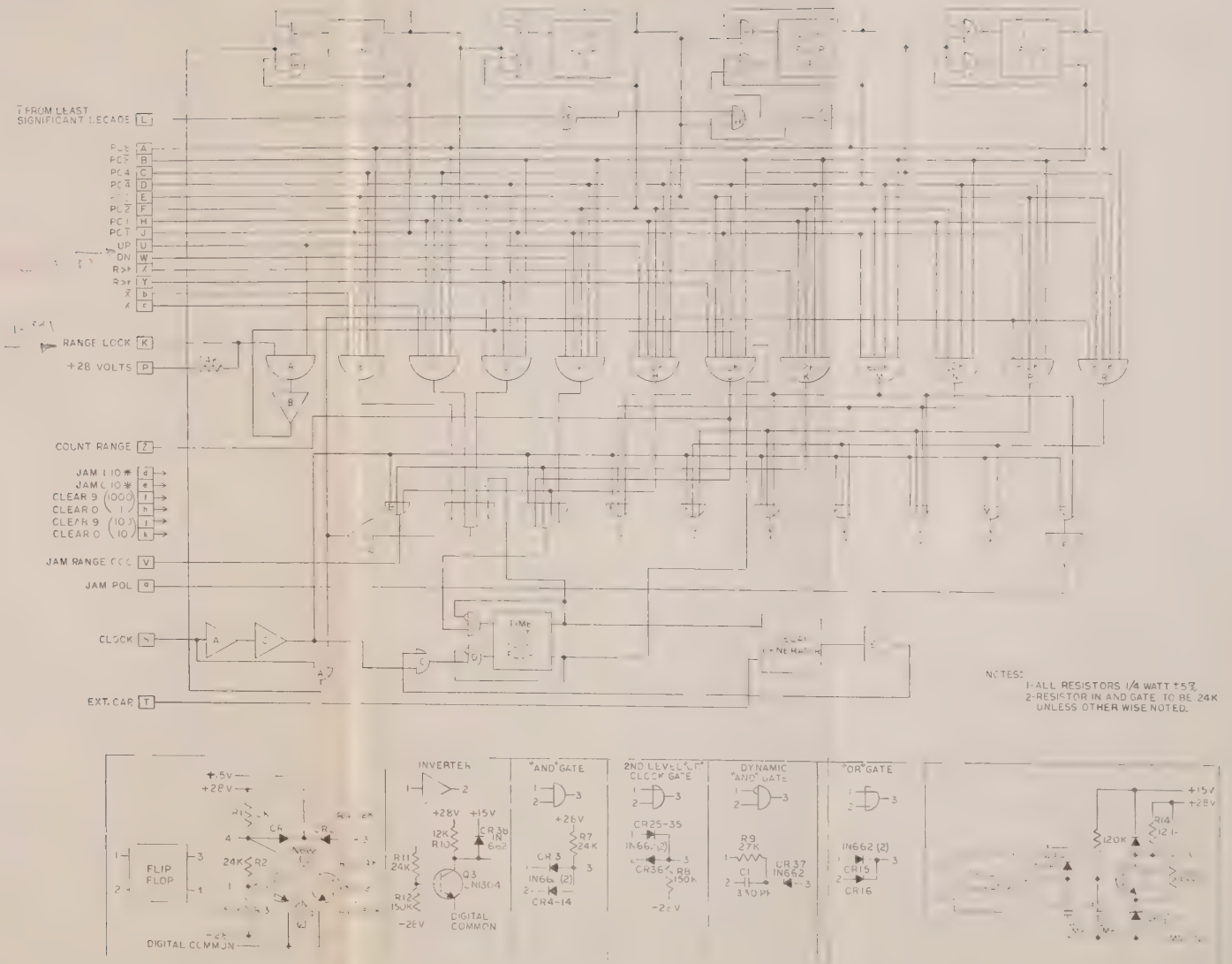


FIGURE 8.6 - Schematic Diagram
Program Counter
(Black-Blue)

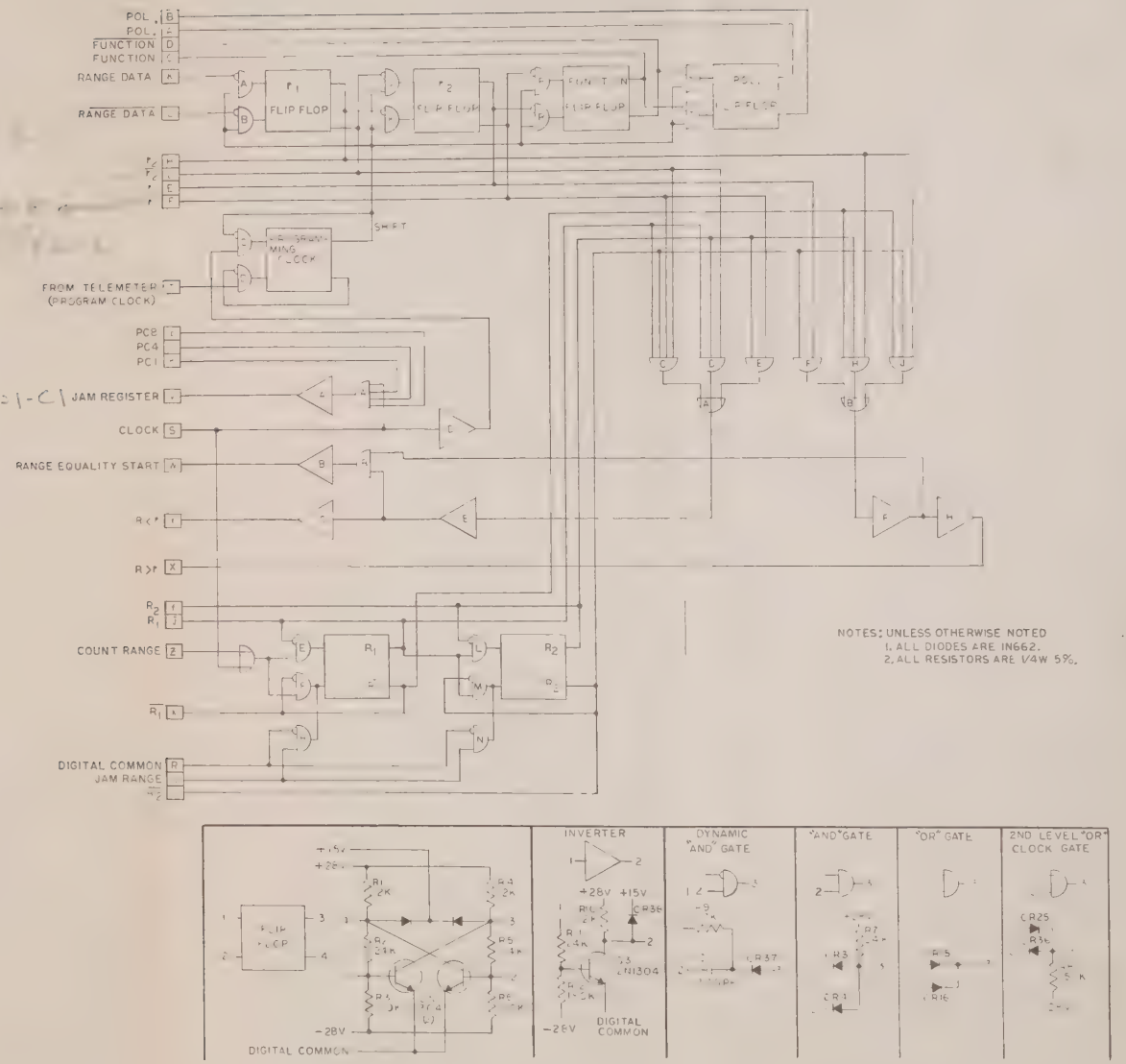
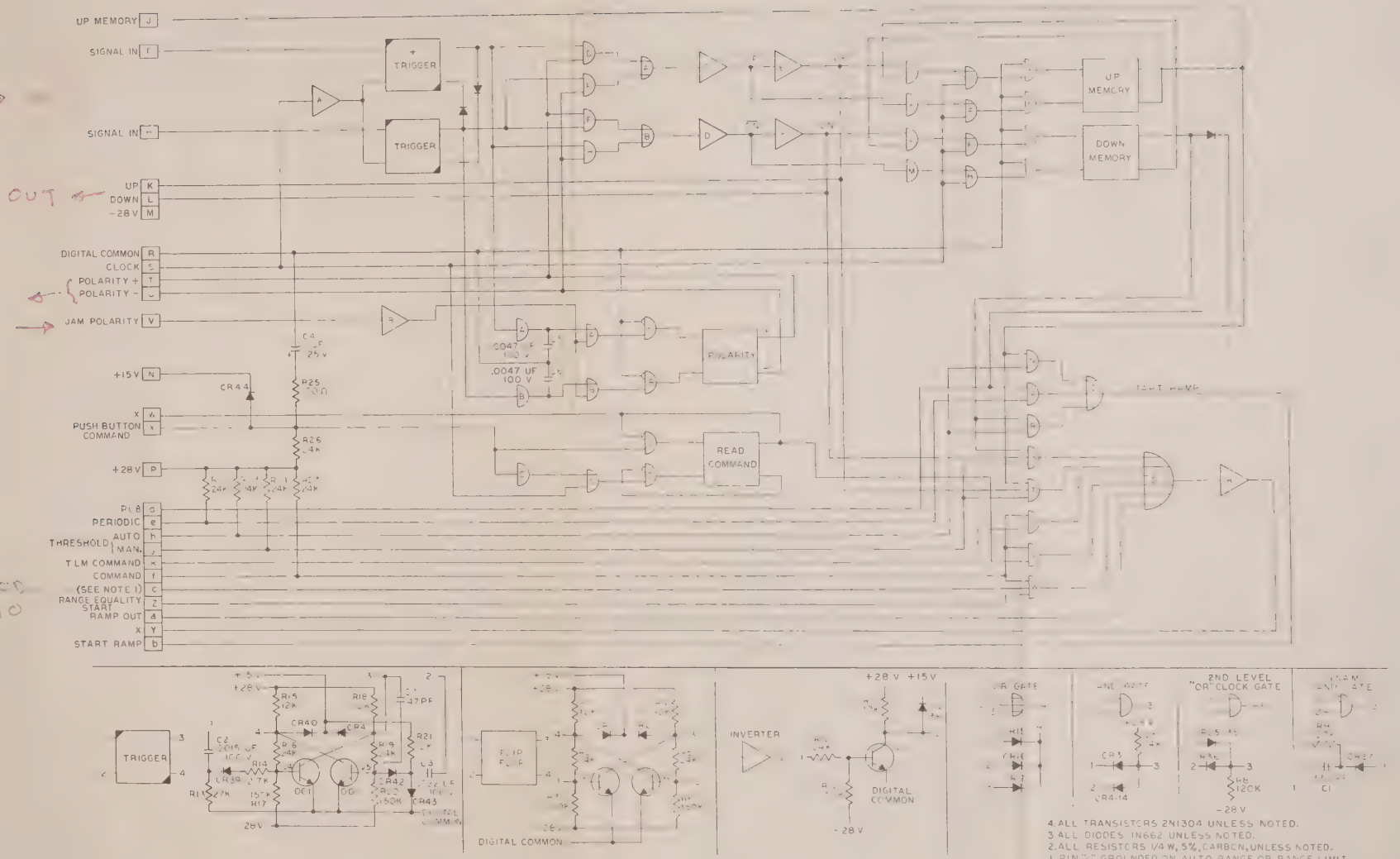


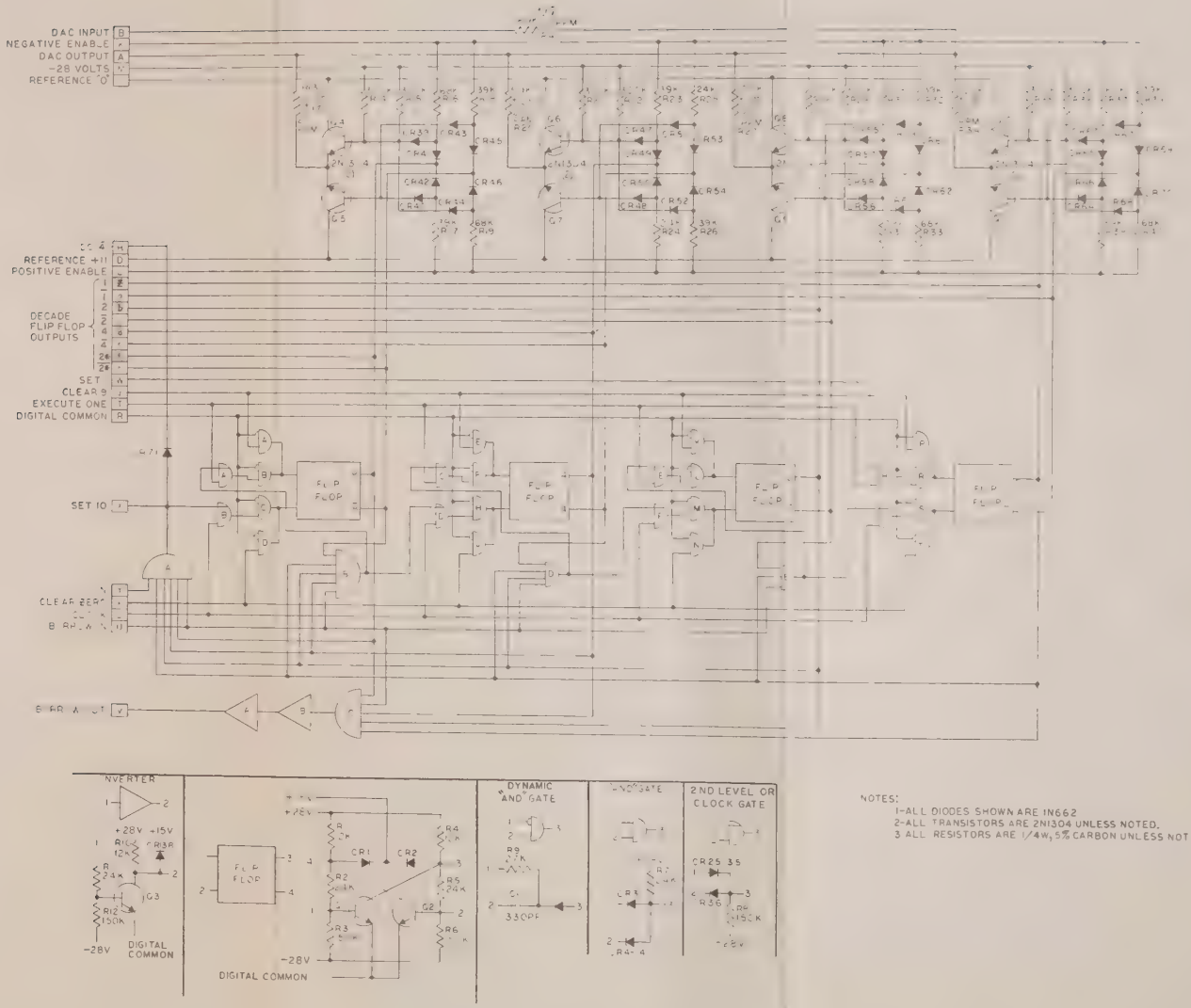
FIGURE 8.7 - Schematic Diagram
Range Counter
(Black-Green)



4. ALL TRANSISTORS 2N1304 UNLESS NOTED.
3. ALL DIODES IN662 UNLESS NOTED.
2. ALL RESISTORS 1/4W, 5%, CARBON, UNLESS NOTED.
1. PIN "C" GROUNDED ON AUTO RANGE OR RANGE LIMIT MODE INSTRUMENTS, OPEN ON FIXED RANGE INSTRUMENTS

NOTES:

FIGURE 8.8 - Schematic Diagram
Correction Logic
(Black-Gray)



NOTES:
1-ALL DIODES SHOWN ARE IN662
2-ALL TRANSISTORS ARE 2N1304 UNLESS NOTED.
3 ALL RESISTORS ARE 1/4W, 5% CARBON UNLESS NOTED.

FIGURE 8.9 - Schematic Diagram
Lower Order Decade
(Black-White)

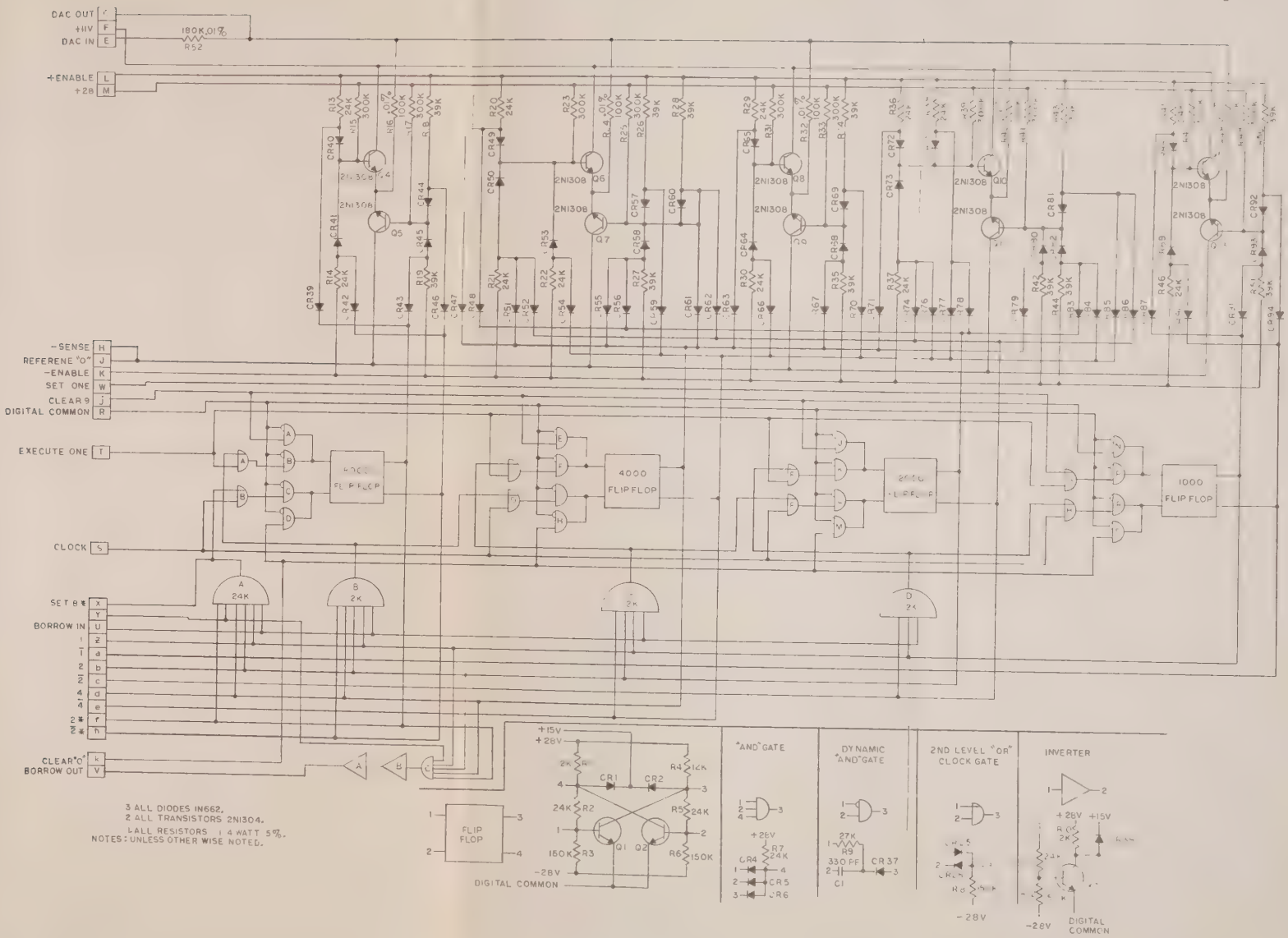


FIGURE 8.10 - Schematic Diagram
1000 Decade
(Brown-Yellow)

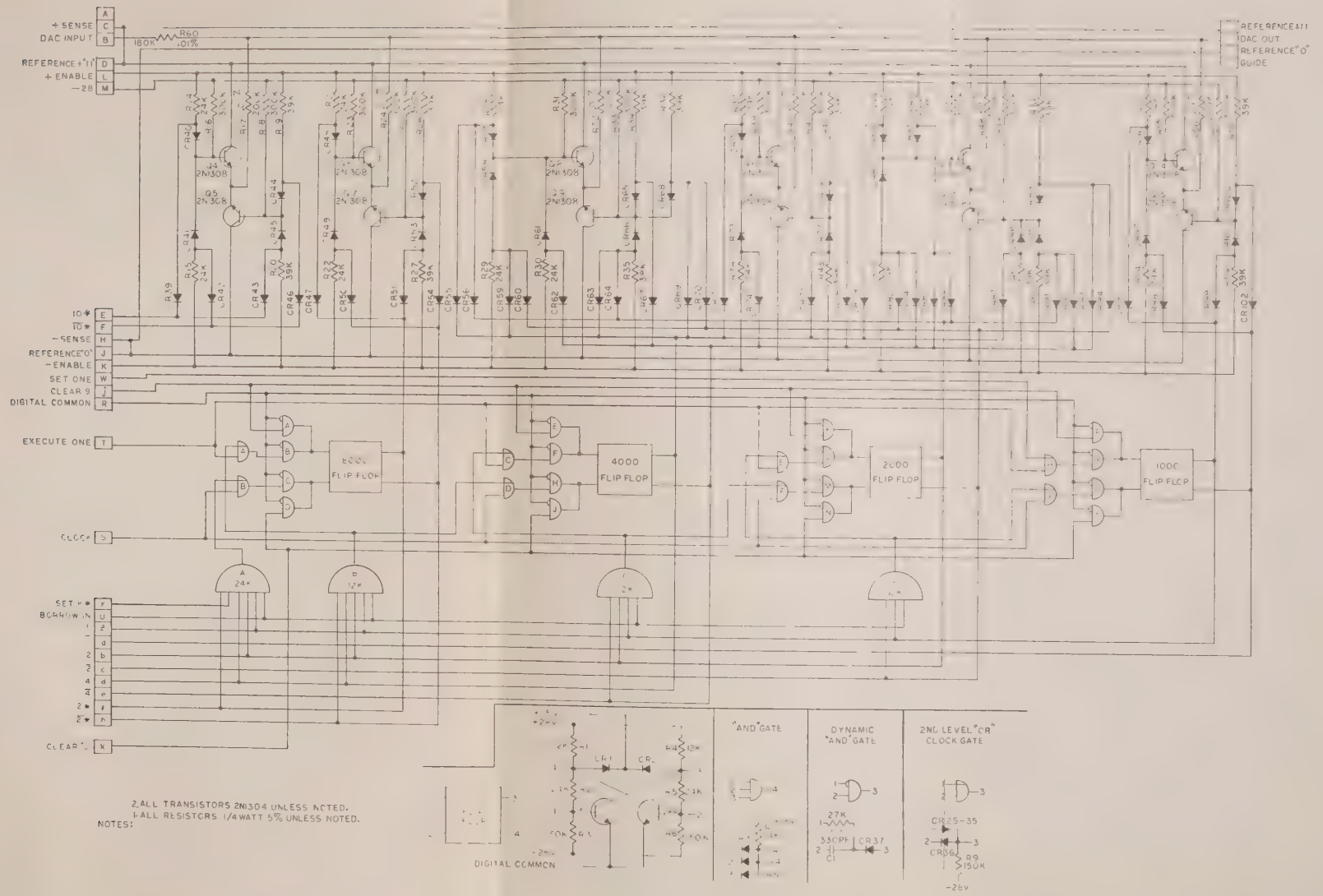


FIGURE 8.11 - Schematic Diagram
10,000 Decade
(Brown-Green)

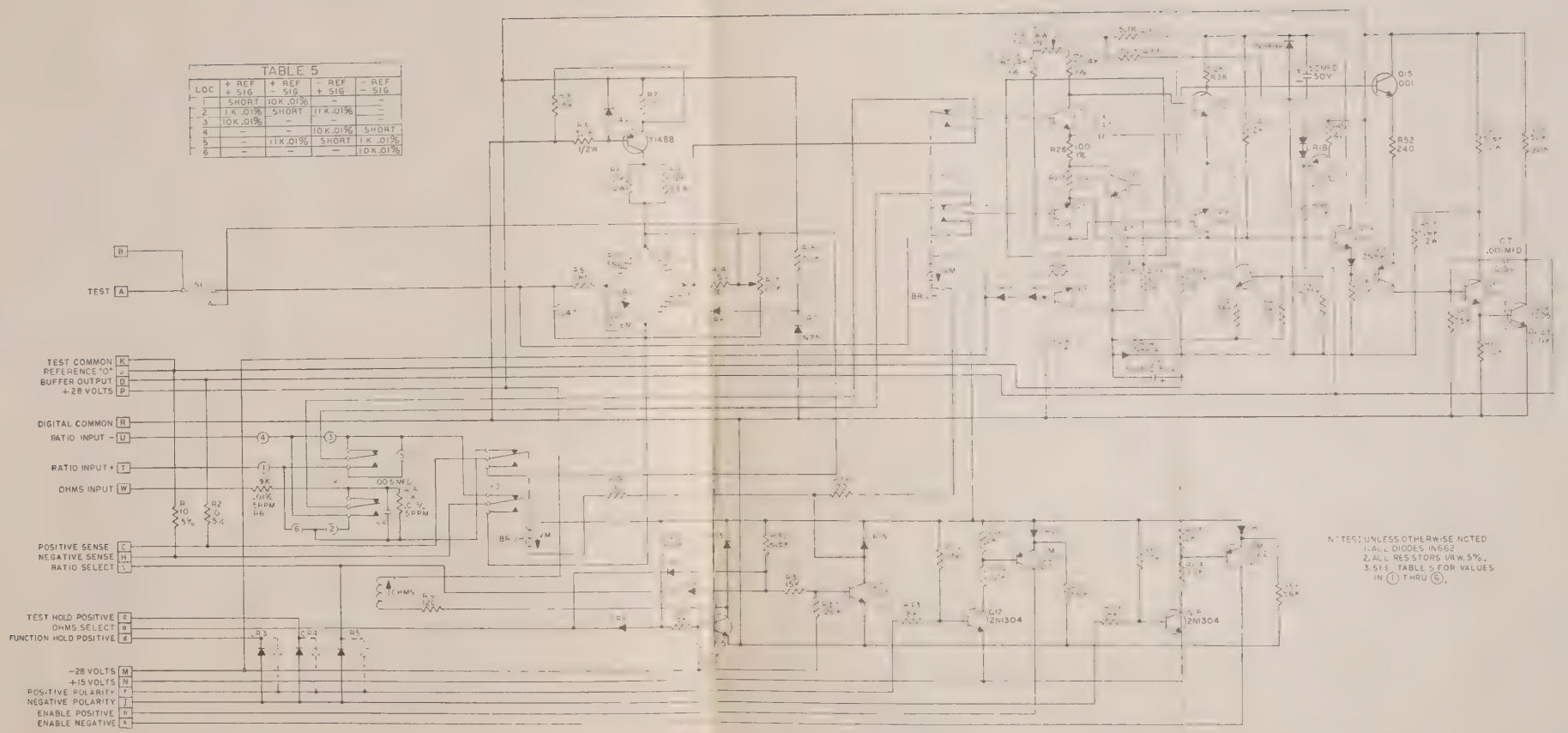


TABLE 5
LOC | + REF + SIG | + REF - SIG | - REF + SIG | - REF - SIG
1 | SHORT | 10K .01% | - | -
2 | 1K .01% | SHORT | 11K .01% | -
3 | 10K .01% | - | - | -
4 | - | - | 10K .01% | SHORT
5 | - | 11K .01% | SHORT | 1K .01%
6 | - | - | - | 10K .01%
TEST
TEST COMMON
REFERENCE "0"
BUFFER OUTPUT
+28 VOLTS
DIGITAL COMMON
RATIO INPUT -
RATIO INPUT +
OHMS INPUT
POSITIVE SENSE
NEGATIVE SENSE
RATIO SELECT
TEST HOLD POSITIVE
OHMS SELECT
FUNCTION HOLD POSITIVE
-28 VOLTS
+15 VOLTS
POSITIVE POLARITY
NEGATIVE POLARITY
ENABLE POSITIVE
ENABLE NEGATIVE
T1488
2N1304
2N1304
NOTES: UNLESS OTHERWISE NOTED
1. ALL DIODES IN662
2. ALL RESISTORS 1/4 W. 5%.
3. SEE TABLE 5 FOR VALUES IN (1) THRU (6).

FIGURE 8.13 - Schematic Diagram
Internal Reference & Buffer
(Brown-Red)

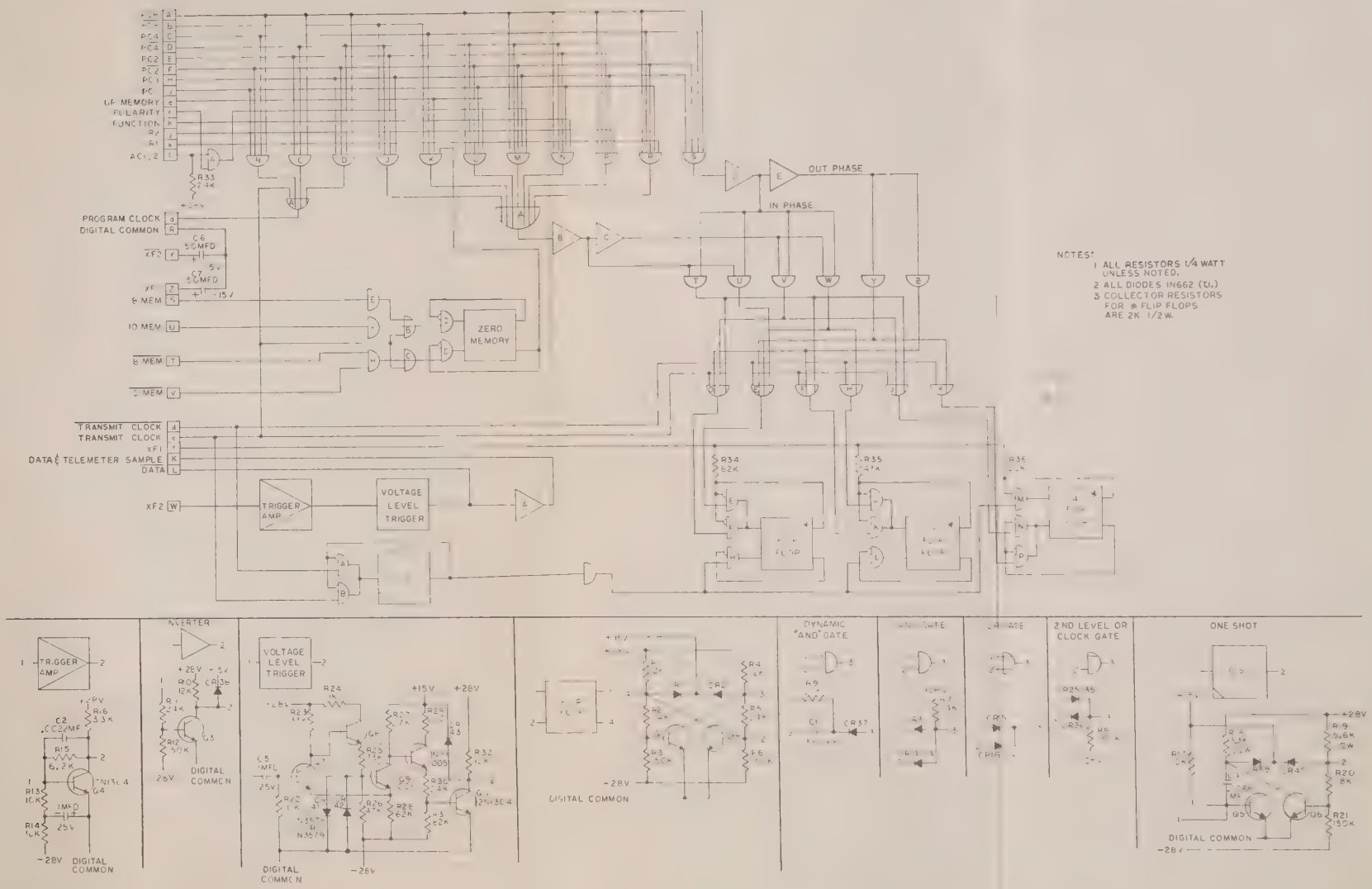


FIGURE 8.14 - Schematic Diagram
PCM Modulator
(Black-Yellow) 1591

Notes:
1. All connectors viewed from wiring side.
2. This wiring diagram contains all output card box wiring common to all 5 digit instruments; Output Option connector wiring is added per the applicable wiring diagrams (Figs. 8.24, 8.25, & 8.26)

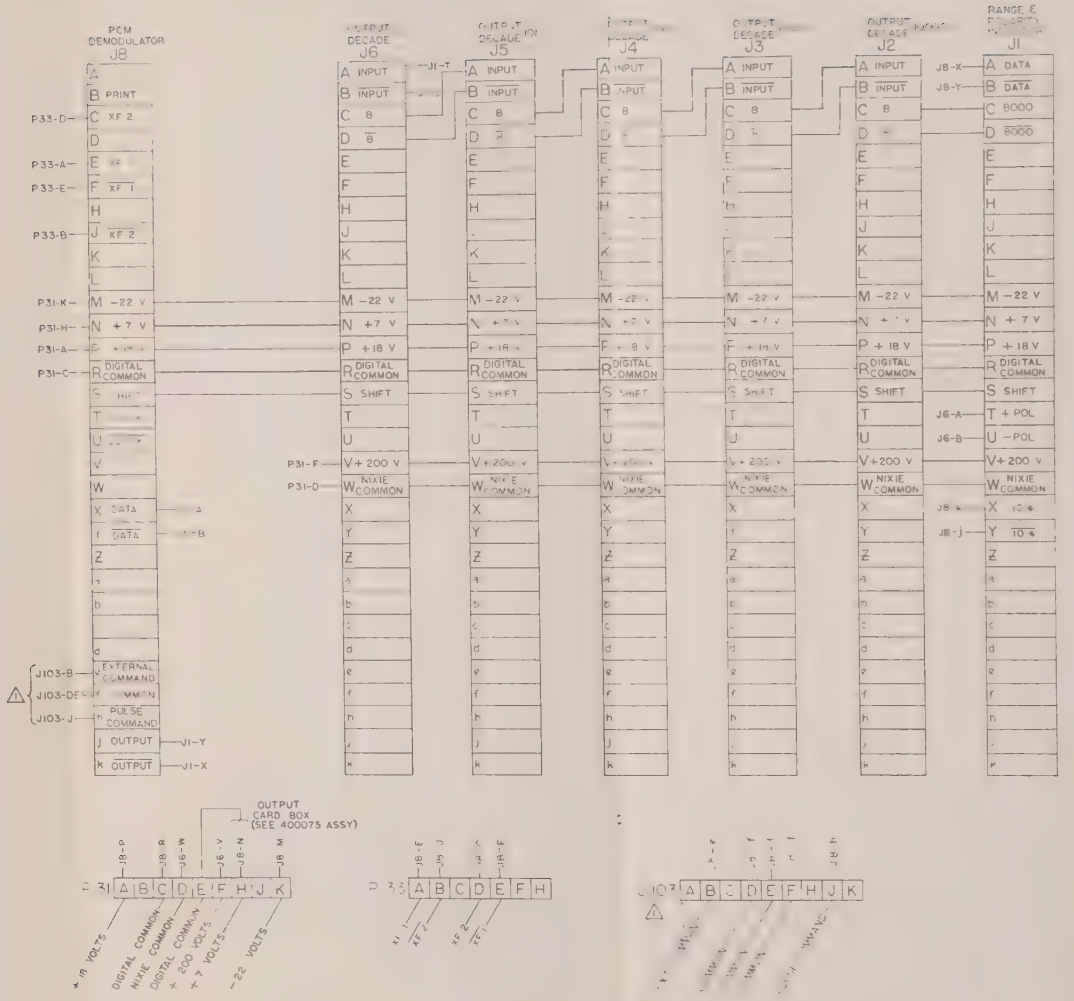


FIGURE 8.15 - Wiring Diagram
Output Card Box (Basic)

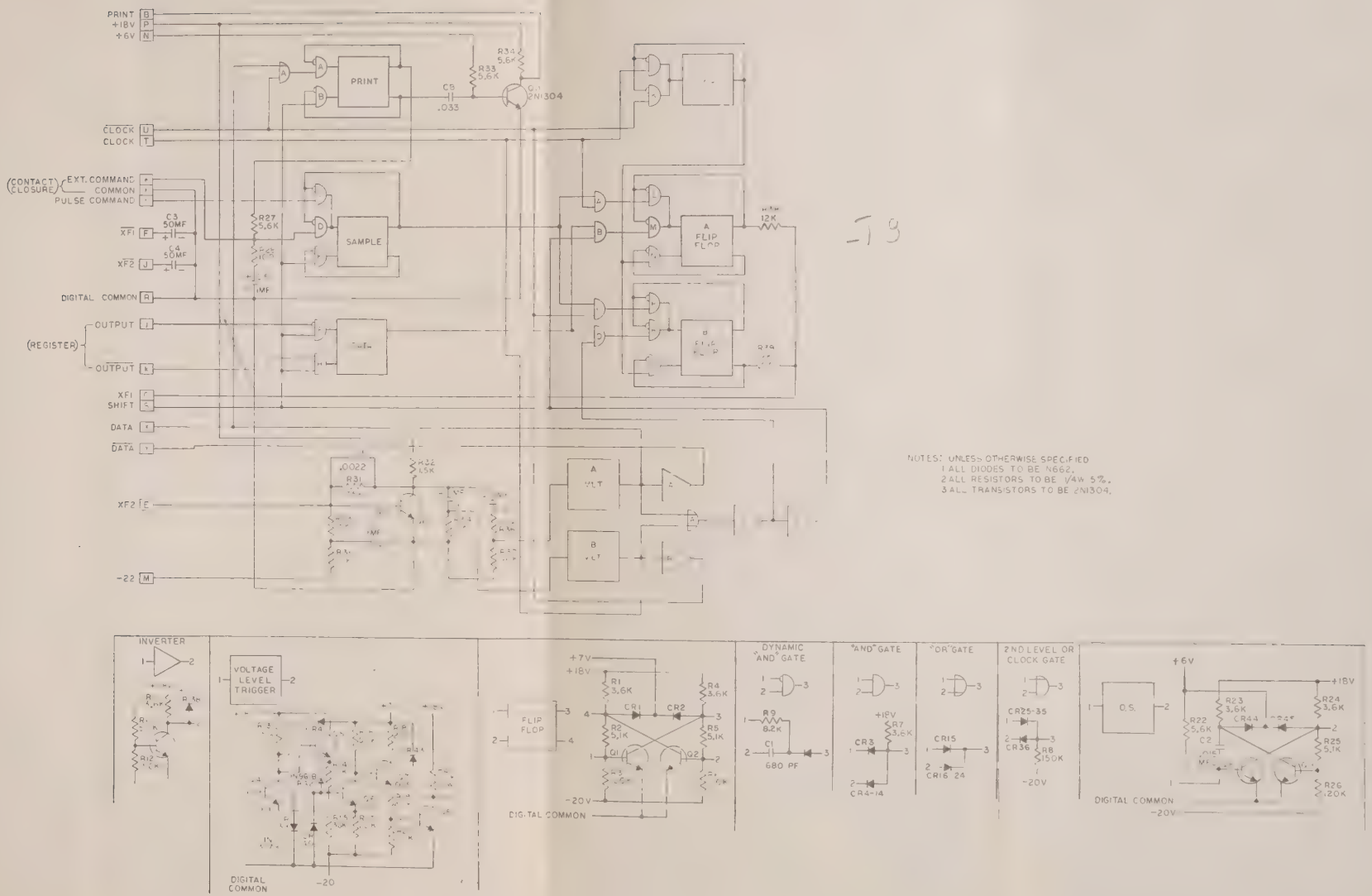


FIGURE 8.16 - Schematic Diagram
PCM Demodulator
(Black-Orange)

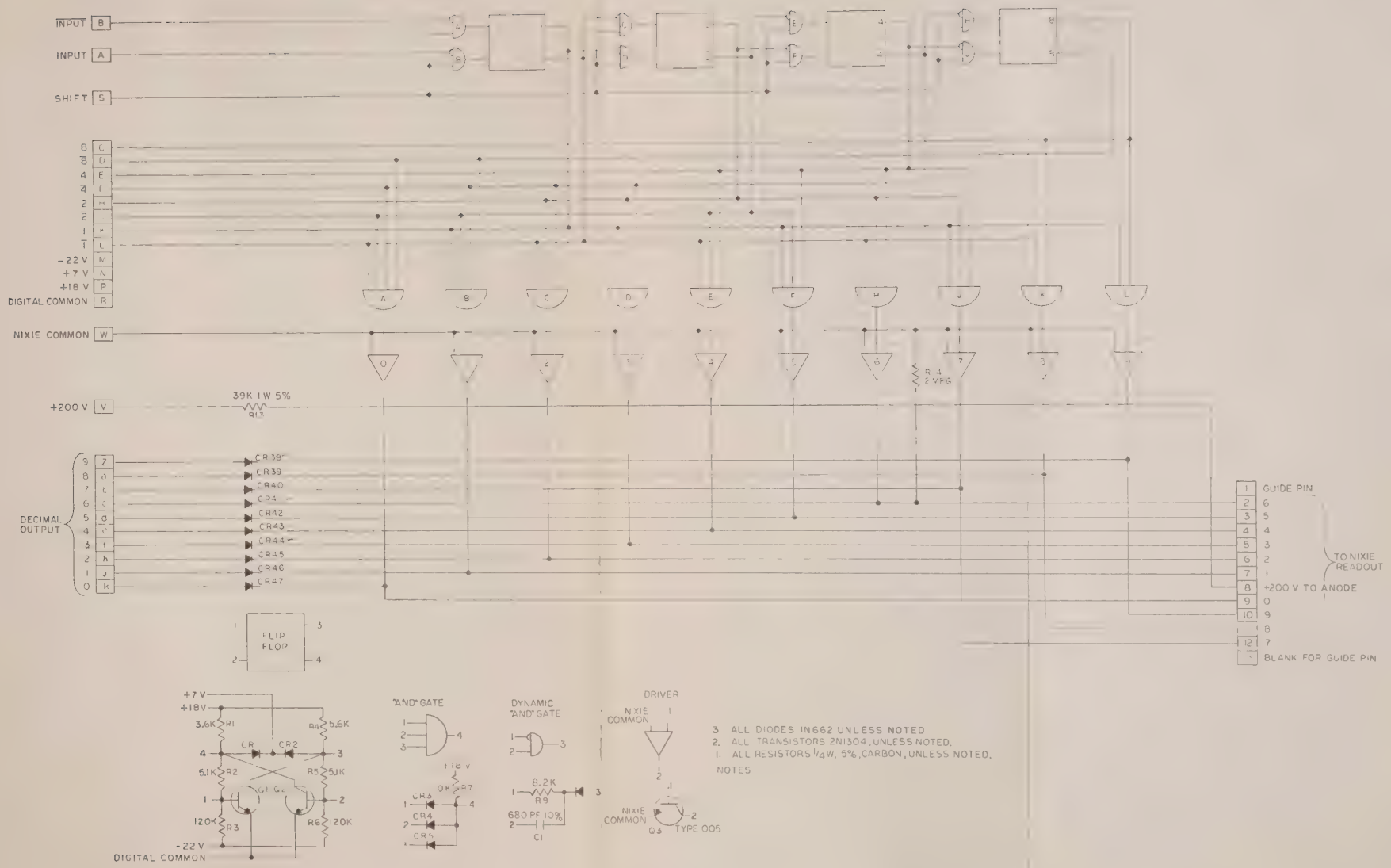
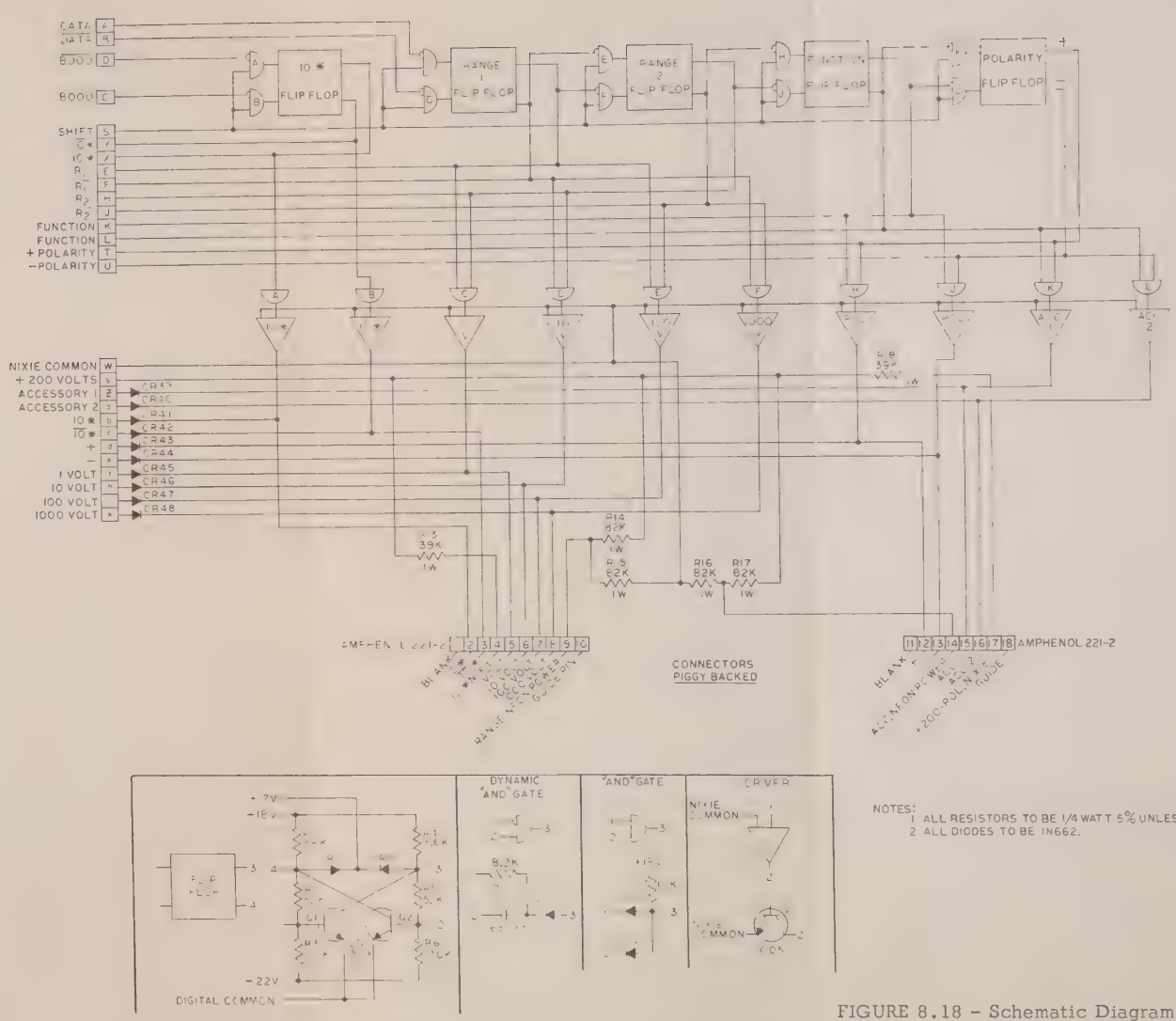
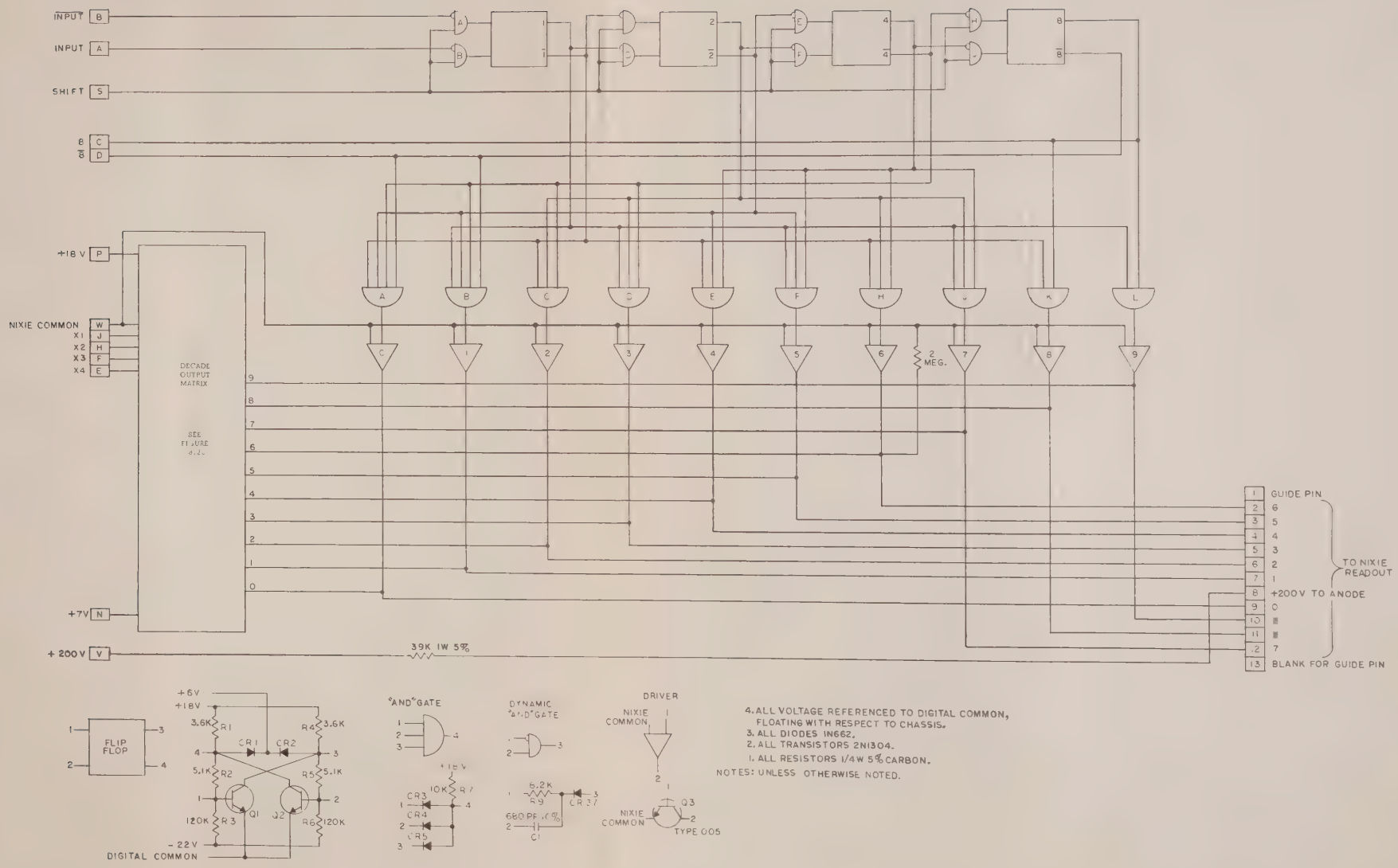


FIGURE 8.17 - Schematic Diagram
Output Decade Option A1 (10 line)
(Black-Red)



NOTES:
1 ALL RESISTORS TO BE 1/4 WATT 5% UNLESS NOTED.
2 ALL DIODES TO BE IN662.

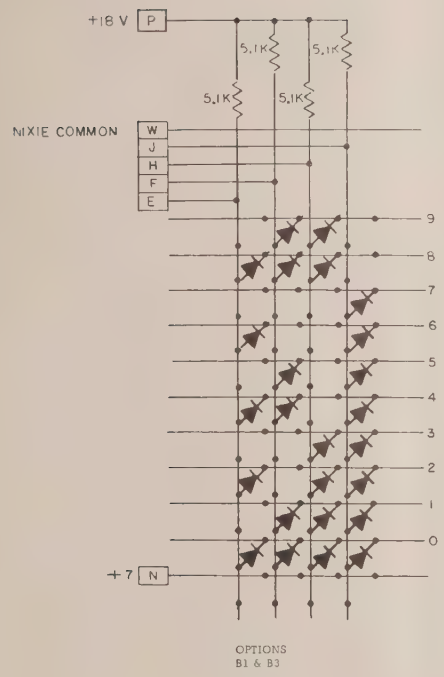
FIGURE 8.18 - Schematic Diagram
Range & Polarity Indicator Option A1 (10 line)
(Black-Brown)



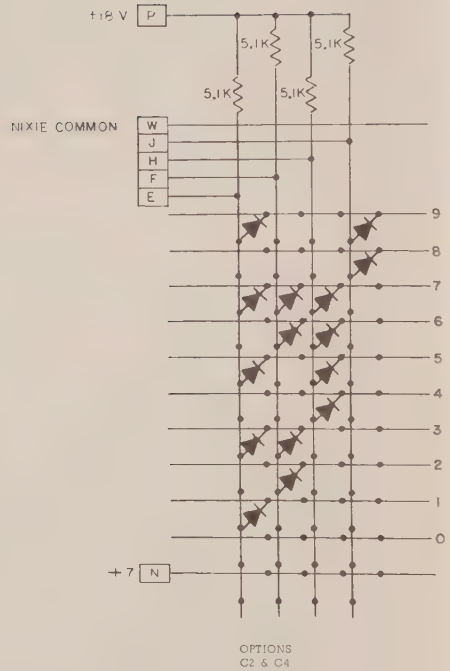
NOTES: UNLESS OTHERWISE NOTED.

1. ALL RESISTORS 1/4W 5% CARBON.
2. ALL TRANSISTORS 2N1304.
3. ALL DIODES IN662.
4. ALL VOLTAGE REFERENCED TO DIGITAL COMMON, FLOATING WITH RESPECT TO CHASSIS.

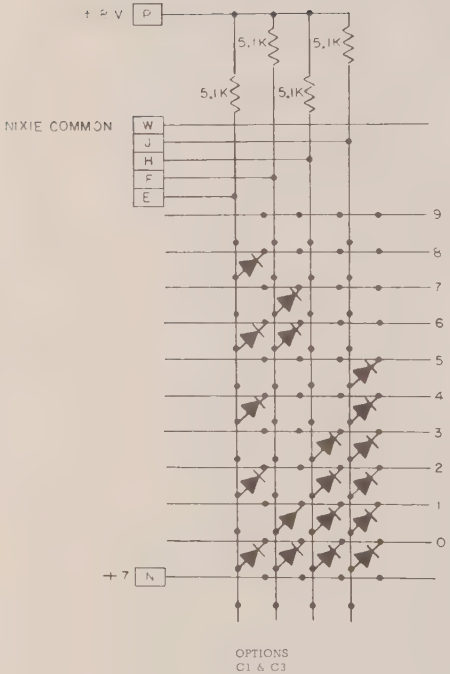
FIGURE 8.19 - Schematic Diagram
Output Decade
(All BCD Options)



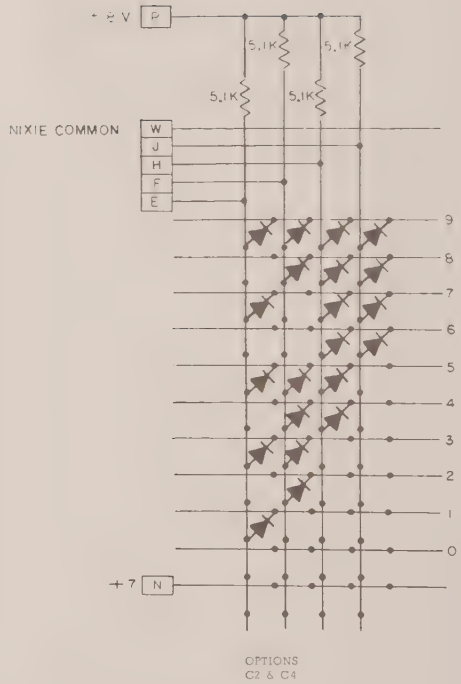
OPTIONS
B1 & B3



OPTIONS
C2 & C4

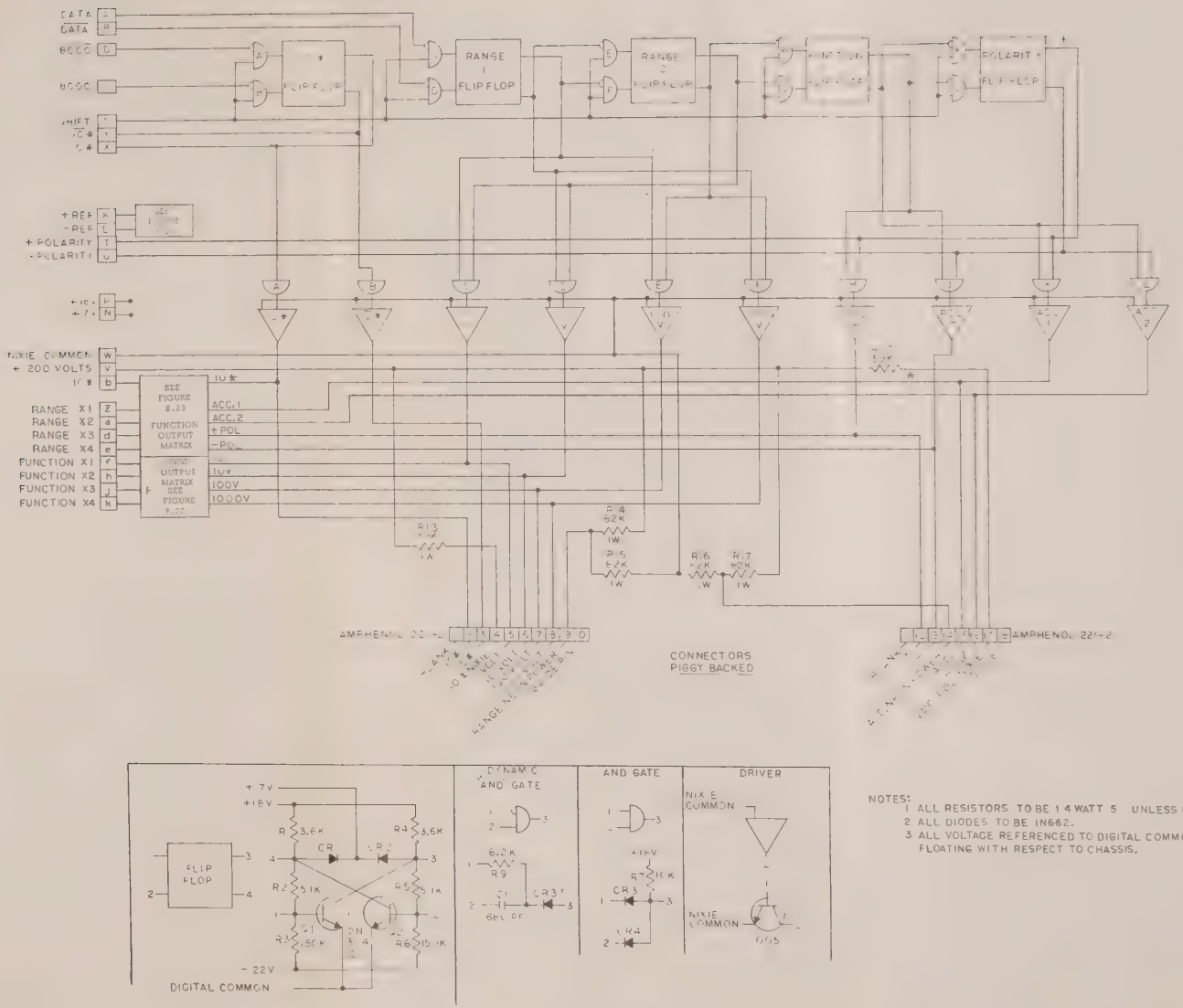


OPTIONS
C1 & C3



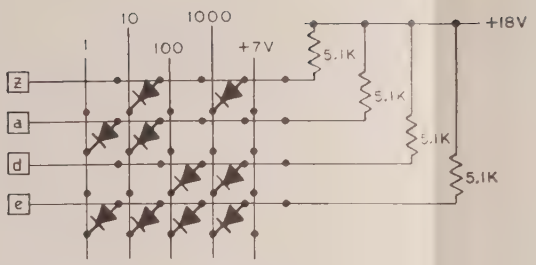
OPTIONS
C2 & C4

FIGURE 8.20 - Schematic Diagram
Decade Matrix

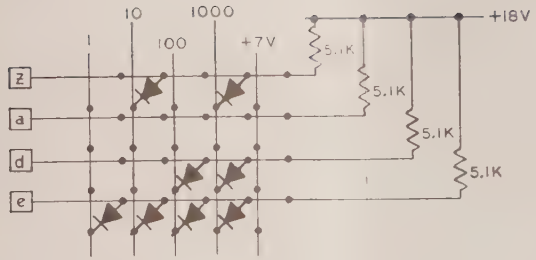


NOTES:
1 ALL RESISTORS TO BE 1/4 WATT 5% UNLESS NOTED.
2 ALL DIODES TO BE IN662.
3 ALL VOLTAGE REFERENCED TO DIGITAL COMMON, FLOATING WITH RESPECT TO CHASSIS.

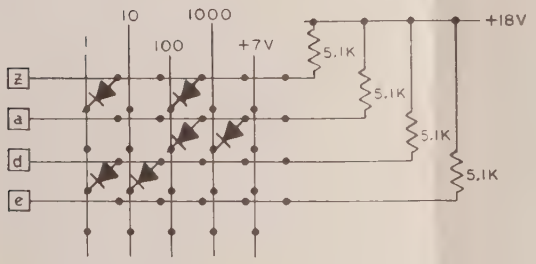
FIGURE 8.21 - Schematic Diagram
Range & Polarity Indicator
(All BCD Options)



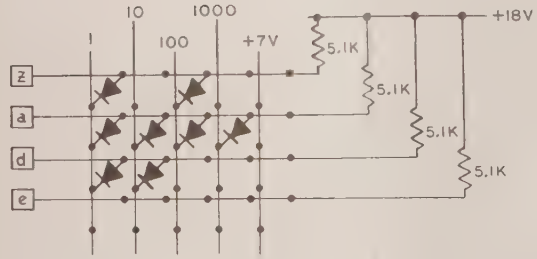
OPTIONS
B1 & B3



OPTIONS
C1 & C3

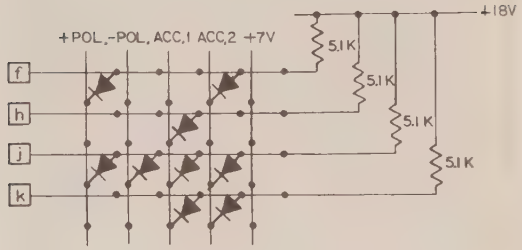


OPTIONS
B2 & B4

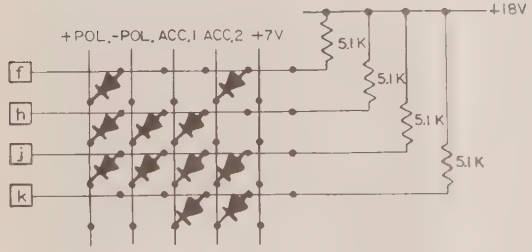


OPTIONS
C2 & C4

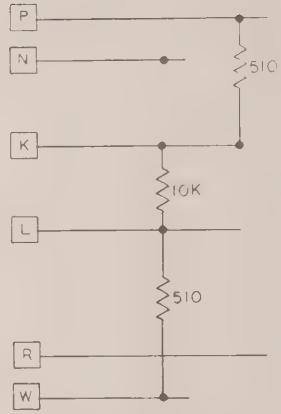
FIGURE 8.22 - Schematic Diagram
Range Matrix



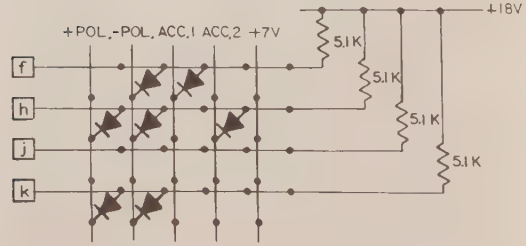
OPTIONS
B1 & B3



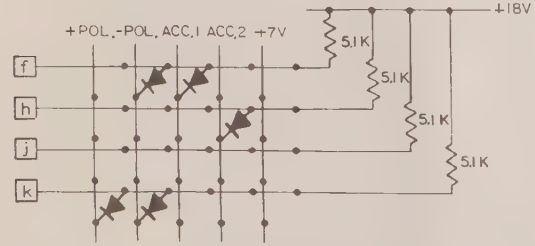
OPTIONS
C1 & C3



BCD Reference Divider
Options B1, B2, B3, B4
C1, C2, C3 & C4

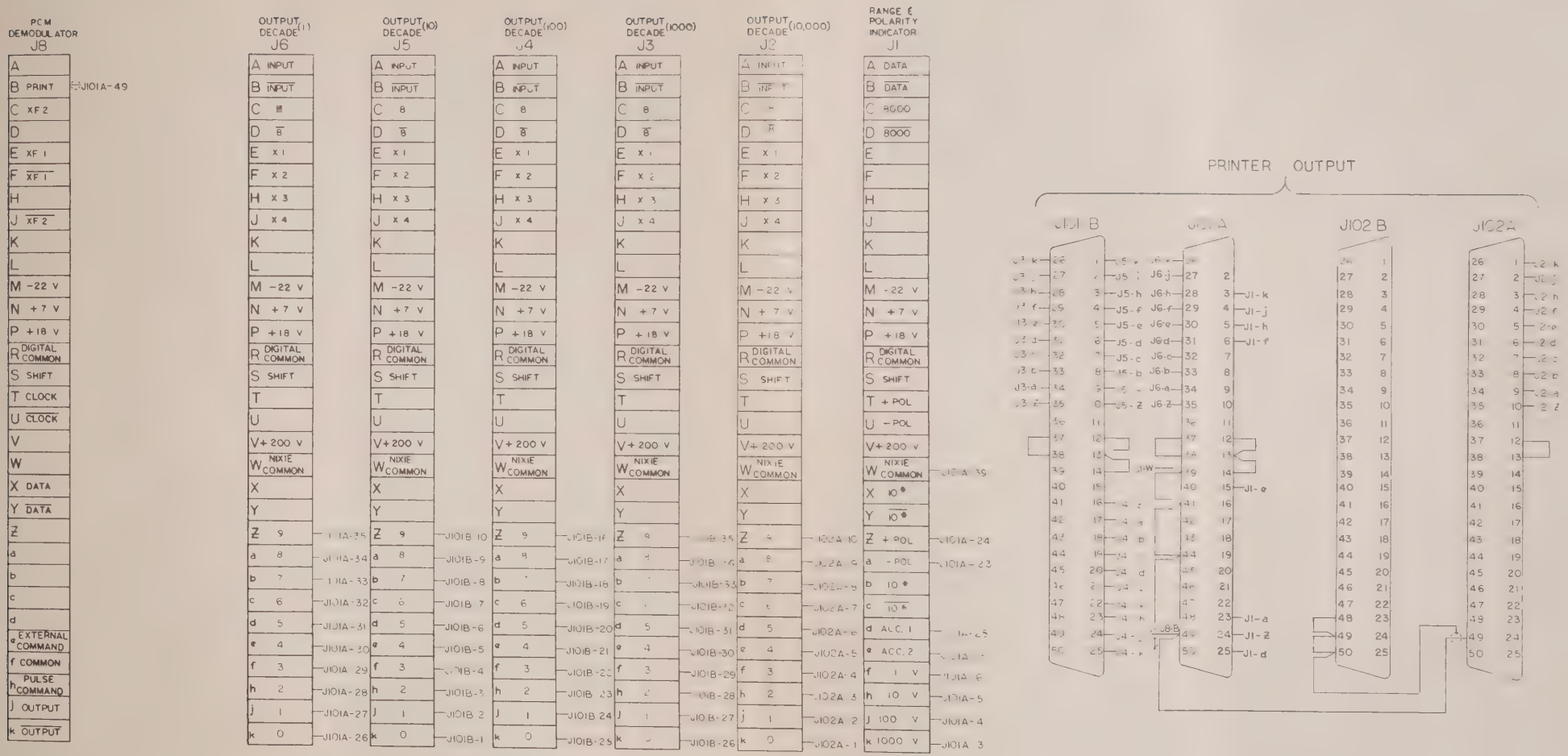


OPTIONS
B2 & B4



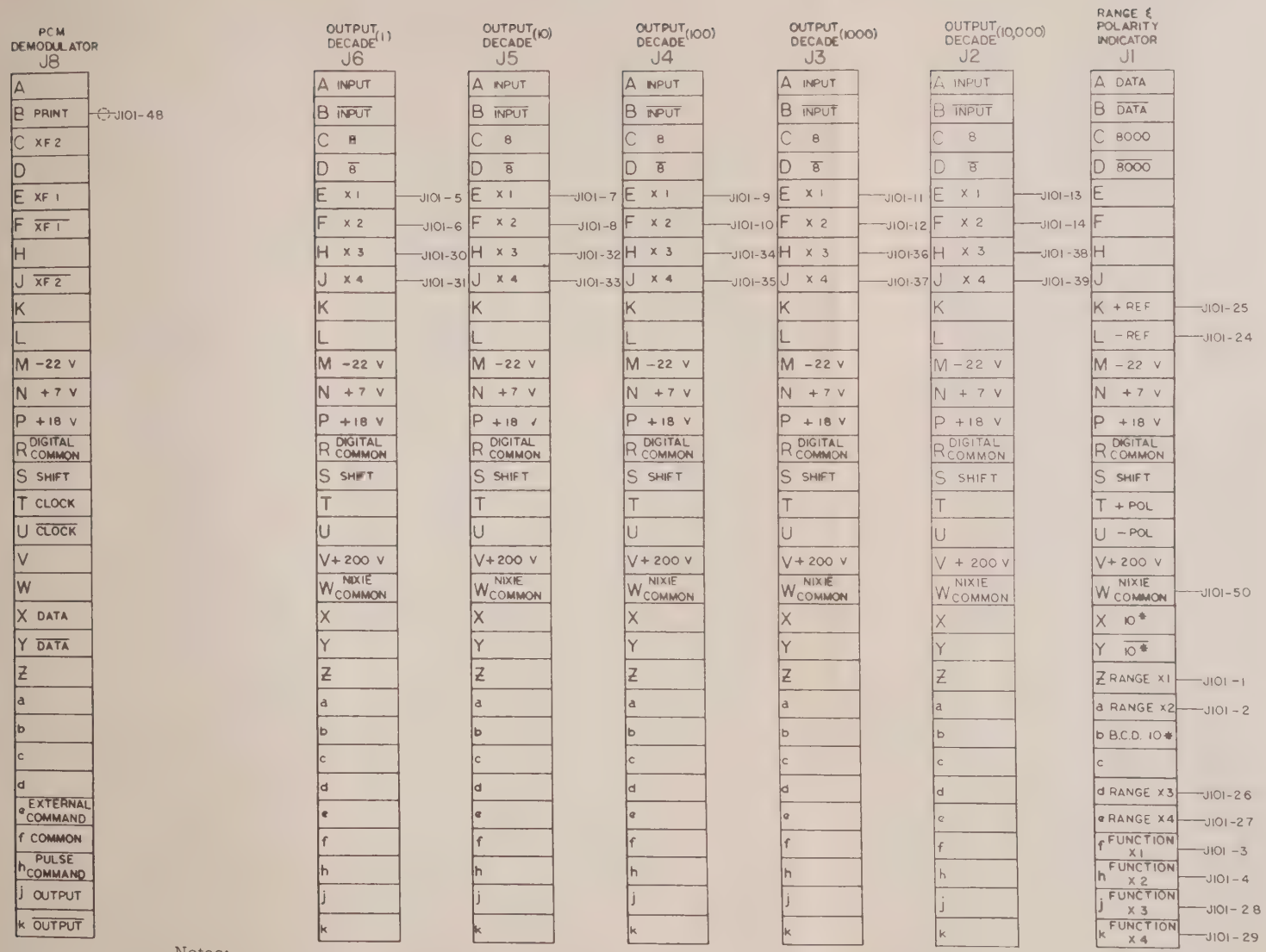
OPTIONS
C2 & C4

FIGURE 8.23 - Schematic Diagram
Function Matrix and BCD Reference



Notes:
1. All Connectors viewed from wiring side.
2. This wiring diagram contains only output option wiring unique to option A1 (10 line); it is in addition to basic diagram (Fig. 8.15)

FIGURE 8.24 - Wiring Diagram
Output Card Box
Option A1 (10 line)



Notes:
1. All connectors viewed from wiring side.
2. This wiring diagram contains only output option wiring unique to options B1, B2, C1, & C2.

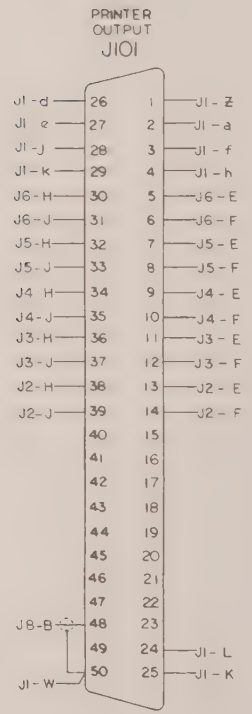
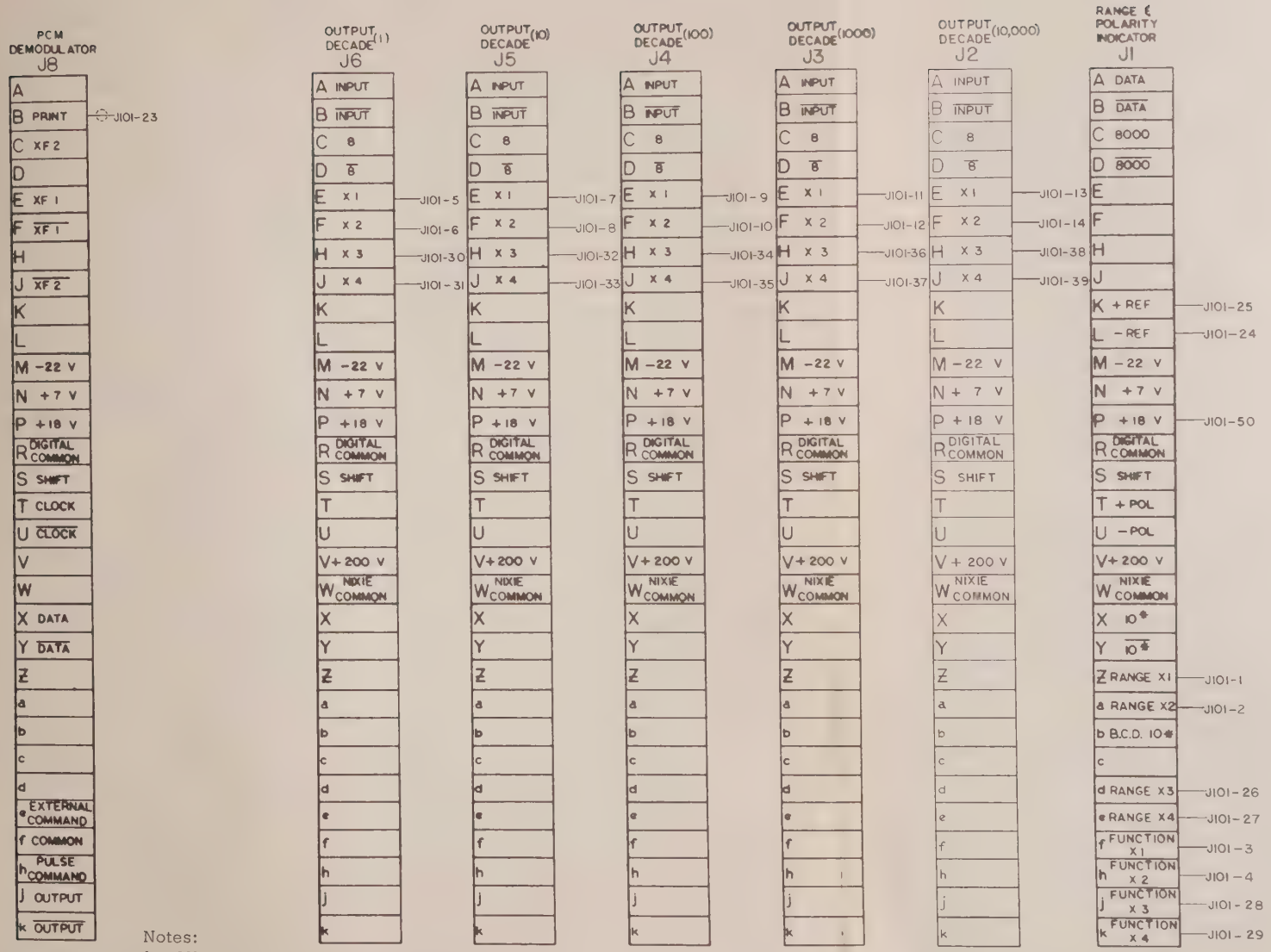


FIGURE 8.25 - Wiring Diagram
Output Card Box
Options B1, B2, C1, & C2



Notes:
1. All connectors viewed from wiring side.
2. This wiring diagram contains only output option wiring unique to options B3, B4, C3, & C4.

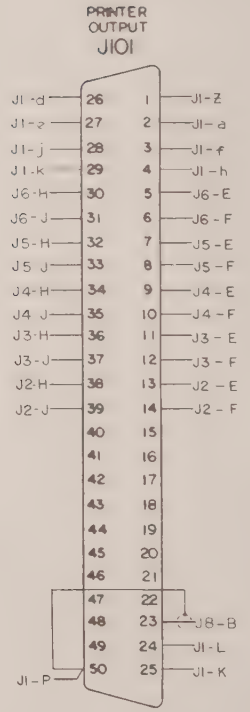


FIGURE 8.26 - Wiring Diagram
Output Card Box
Options B3, B4, C3, & C4

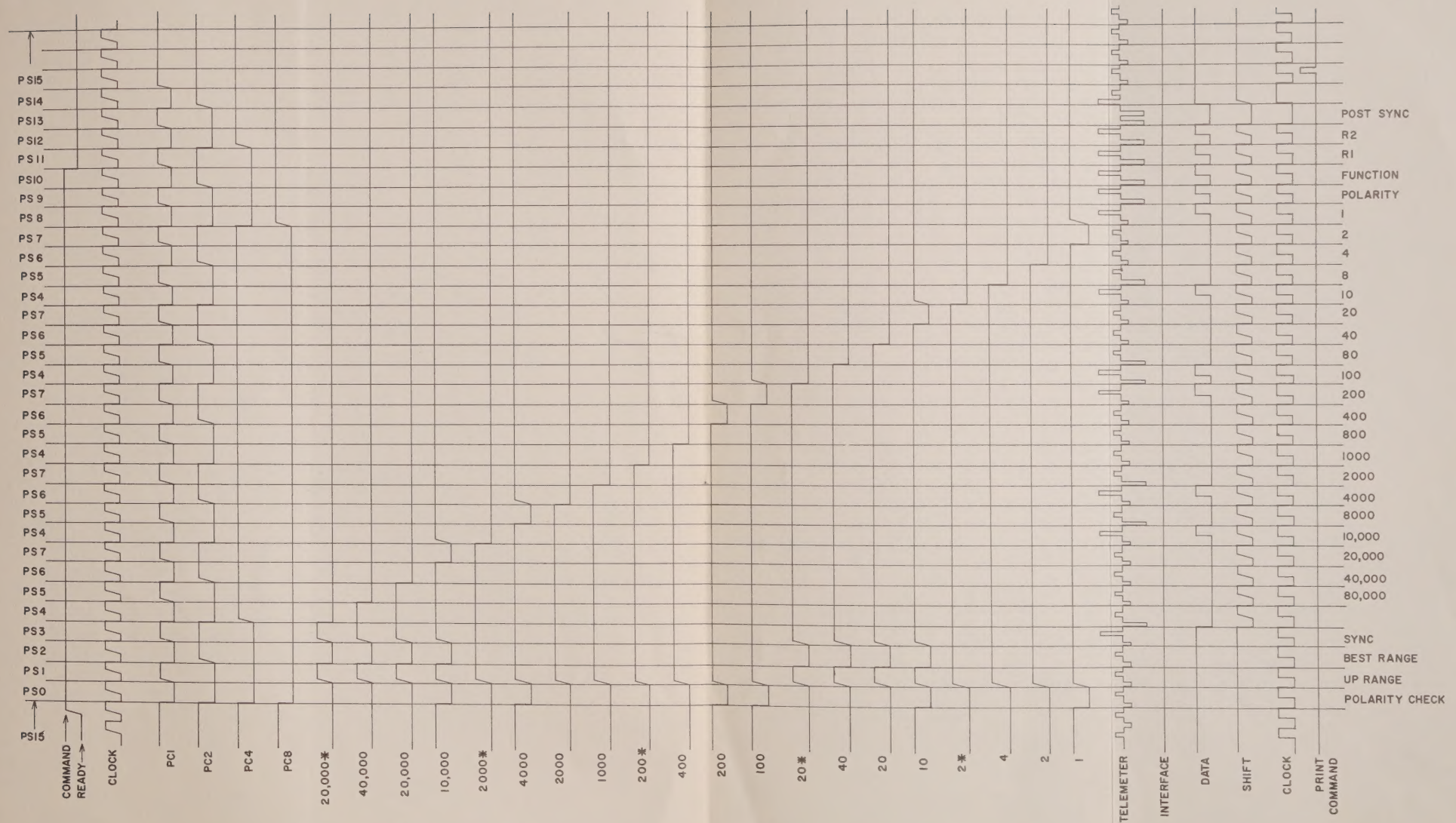
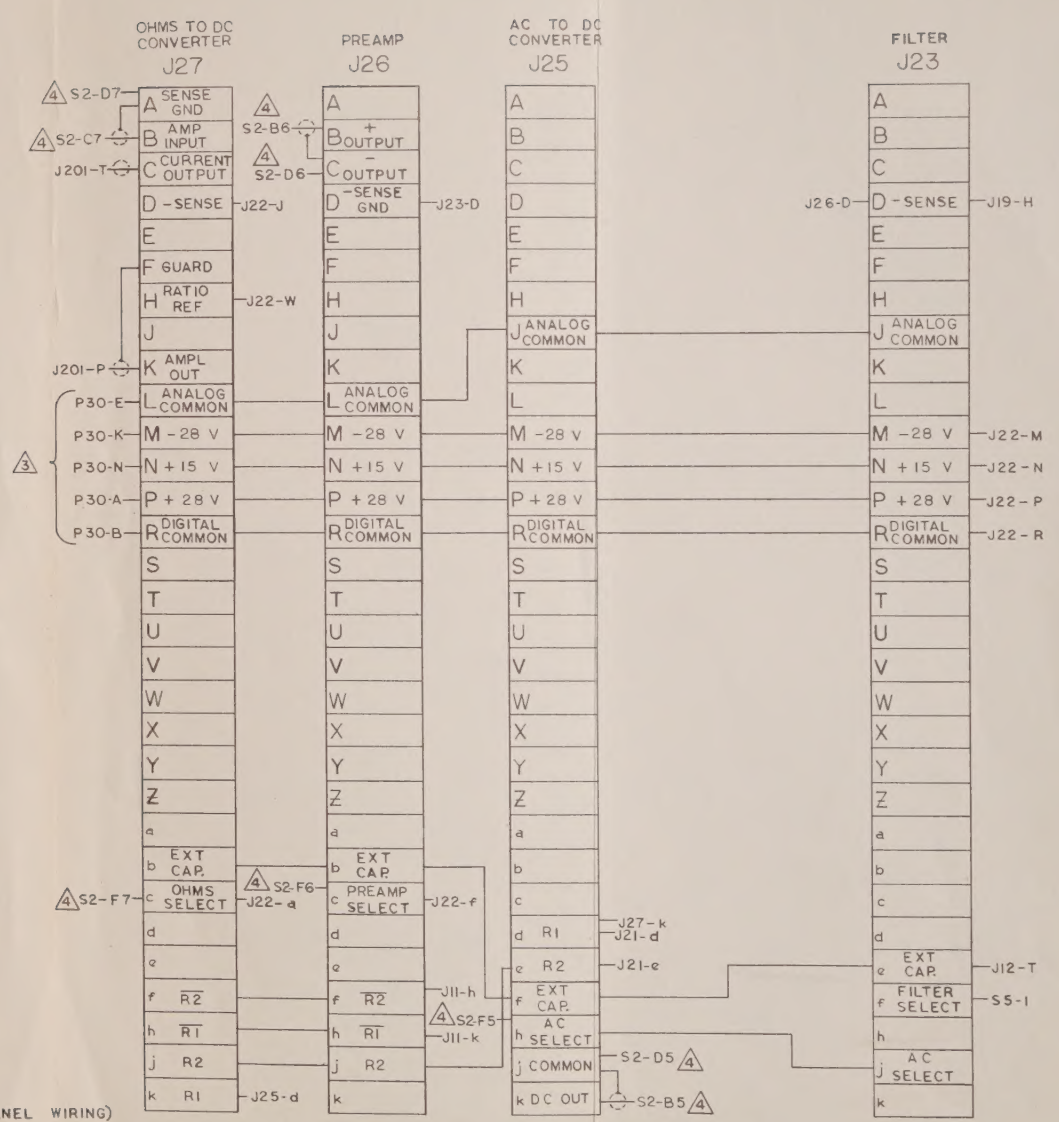


FIGURE 8.27 - DVM Timing Diagram



4 S2 WIRING SHOWN ON 430036 & 430037 WIRING DIAGRAMS (BASIC 4 & 5 DIGIT CONTROL PANEL WIRING)

3 P30 WIRING SHOWN ON 430009 & 430013 WIRING DIAGRAMS (BASIC 4 & 5 DIGIT FLOATING CARD BOX WIRING)

2. THIS WIRING DIAGRAM IS BASIC TO ALL 4100 & 5100 SERIES UNITS; UNITS WITH REMOTE PROGRAMMING ACCESSORY ARE WIRED PER PERTINENT INDIVIDUAL ACCESSORY WIRING DIAGRAMS

NOTES: 1. CONNECTORS VIEWED FROM WIRING SIDE

FIGURE 8.28 - Wiring Diagram
Accessory Basic

MP MASTER
MA30573